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'SALYUT' SPACE STATION IN ORBIT

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SALYUT SPACE STATION IN ORBIT

"Salyut na Orbite"; Mashinostroyeniye Press; Moscow, Russian, 1973, 160 pp]

Subtitle: Fundamentals of the Design of the "Salyut" Orbital station, its flight stages and scientific research material

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ABSTRACT

The basis for this book is the data from the scientific work of the heroic crew of the first Salyut long-term orbital scientific station -- USSR cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev.

The structural features and the scientific equipment of the Salyut station are described for the first time. Broad information and flight documents of the station and excerpts from the logs and notebooks of the cosmonauts, and fragments of their radio conversations with the flight control center are presented. The data from the scientific research and experiments performed onboard the station are generalized.

The book is illustrated by unique photographs taken from onboard the station, most interesting frames from onboard movies, diagrams and photographs in color. It is designed for a broad class of readers. There is 1 table and 62 illustrations.

FOREWORD

The idea of building long-term manned stations in space is not new. Long before the beginning of the space age, our famous compatriot Konstantin Eduardovich Tsiolkovskiy foresaw the possibility of settlements in space. He wrote: "Mankind will not always remain on the Earth, but in the pursuit of light and space he will at first timidly penetrate beyond the limits of the atmosphere and then conquer all of the solar system."

Now we are the witnesses to the realization of the ingeneous predictions of the founder of cosmonautics K. E. Tsiolkovskiy. The Soviet people are proud of the fact that our country has blazed mankind's trail into space.

The Soviet space program has been recognized as making a great contribution to the development of the socialist national economy. On the given level this has actually been promoted by research [translator's note: remainder of foreword not provided in Russian text].

SALYUT LONG-TERM ORBITAL SCIENTIFIC STATION

Introduction

The Salyut is a multipurpose orbital scientific station capable of solving a broad class of problems in the space about the Earth. Its creation marked a new step in the development of the USSR manned space flight program.

The experience in the development and testing of manned spacecraft of the Soyuz series greatly promoted the acceleration of the planning, design and production work for building the Salyut station and preparing it for flight.

During flight of the long-term Salyut orbital scientific station, two basic missions were to be accomplished: a study of the possibility of prolonged existence of man in space and the performance of a broad program of scientific experiments.

In solving the first of these problems provision was made for a large medical-biological experimental program with the participation of the station crew members. A set of devices was developed providing for comprehensive physical training of the commonauts in flight since the physical load permits a definite degree of compensation for the absence of gravitational force during a prolonged stay in space and it creates the conditions for acceleration readaptation of the human organism after returning to the Earth.

In solving this problem it was necessary to place a large number of scientific instruments and tools in the station compartments, the total mass of which exceeded 1,200 kg.

When planning and designing the station, it was also considered that the performance of a saturated program of scientific-engineering experiments and testing of onboard systems and units under complex conditions of prolonged space flight would offer the first experience in the operation and maintenance of the new type of spacecraft -- manned orbital stations.

The developers of the Salyut station were faced with the problem of creating a long-term scientific space laboratory manned in orbital flight by crews operating in shifts. In order to deliver and return the crews, transport individual elements of equipment, objects and results of the study provision was made for using the Soyuz series spacecraft.

When building the Salyut station the plancalled for performing scientific research onboard it both when it was manned, when the transport ship docked with the orbital unit of the station and the crew was inside and during flight of the orbital unit of the station in the automated mode without a crew.

According to the plan, part of the results of the scientific research performed on the station had to be transmitted to the Earth by a radio telemetric system; the other part was to be delivered in the transport space ship. Thus, provision was made for the possibility of transporting photographic and movie materials, photoemulsion units, containers with biological specimens, onboard logs with scientific observations of the astronauts from orbit to the Earth.

A large collective of scientists, designers, engineers, technicians and industrial workers were drafted to work on building the Salyut orbital scientific station. The USSR cosmonauts already having experience in space flights participated directly in the developments.

As a result of the work done, one of the heaviest and most complicated spacecraft launched into Earth orbit was built. The orbital station included the following: an orbital module inserted into orbit without a crew and a transport ship with crew launched by a separate booster rocket and docked in orbit with the orbital unit. The crew included the commander, the onboard engineer and the research engineer.

The total mass of the station after docking was 25,600 kg, including the mass of the orbital unit after launching into orbit of 18,900 kg and the mass of the spaceship in orbit 6,700 kg. More than 1,300 separate instruments and units were put onboard the station.

The geometric characteristics of the station are as follows: total length docked 23 meters, length of orbital module 16 meters, maximum diameter of the orbital module 4.15 meters, maximum transverse dimensions of the station with respect to the open solar cells 11 meters.

In order to perform scientific experiments, visual observations, take photographs and movies, there are 27 lights in the station compartments.

For transferring the crew from the transport ship to the orbital module and back there is a docking unit. After docking the crew can work and rest both in the station compartments and in the transport ship by crossing directly through the docking unit without going into outer space.

In accordance with the direction taken in Soviet space engineering in the manned compartments of the station in orbit the Earth gas composition and atmospheric pressure are maintained in the manned compartments of the station in orbit insuring the best conditions for vital support of the cosmonauts.

On the Salyut station provision has been made for the first time for the possibility of the repair and replacement of apparatus and equipment in flight by the crew itself. The placement and composition of the equipment and instruments are arranged considering the possibility of access to them in case of damage or failure. There were a set of tools, fittings and certain spare parts kept onboard the station.

Orbital Module

When planning, designing and making up the composition of the orbital module of the station it was necessary to provide maximum comfort in flight for the station crew (spacious internal compartments, convenient control statinss for operation, places for the crew to rest and sleep), a good view of surrounding space and also convenient placement of sensors, optical instruments and scientific equipment. The observation instruments were assembled in such a way that in the lower part of the station (along the -y-axis) it was possible to observe the Earth and Sun and in the upper part (along the +y-axis), the stars.

In order to insure maximum illumination of the solar battery panels in flight, the station could be oriented on the Sun in the mode of rotation around the transverse axis. The problem of stable rotation of the station in this mode was solved by creating the predominant moment of inertia around the axis perpendicular to the plane of the solar cell panels, over the moments of inertia with respect to the other axes. This required special composition of the station equipment.

The structure of orbital module of the Salyut station was designed for insertion of it into orbit without using the overall protective nose fairing. For protection of some of the external elements (the solar cells, lights, antennas, and so on) from aerodynamic and thermal loads arising in the active part of insertion, the local fairings and covers were used which are discarded after passage through the dense layers of the atmosphere.

The orbital module comprises two sealed comparements (the transfer compartment and the working compartment) and one unsealed compartment (the apparatus compartment).

The transfer compartment is executed in the form of a cylinder 2 meters in diameter and 3 meters long. In the forward section there is a docking unit designed for rigid docking of the transport spacecraft with the orbital module. On the opposite side of the compartment there is a hatch for transfer to the working compartment. In the transfer compartment there is part of the scientific and photographic equipment (the internal units of the Orion stellar telescope, cameras, the modules for biological experimentation) and also the the Orion telescope control panel. Along with the telescope control panel a lock has been provided for bringing the stellar telescope film cartridges into the station after completing the experiment.

On the outside surface of the transfer compartment the following have been installed:

The external modules of the Orion stellar telescope (they are in a special spherical depression imbedded in the transfer compartment);

Two solar sell panels (left and right);

The antennas of the rendezvous radio equipment;

The optical light for orientation during manual docking of the spacecraft with the station;

One of the external television cameras;

Panels with the heat regulating system units (the hydraulic pumps, the liquid flow rate regulars, the expansion tanks, and so on);

The ion sensors of the station orientation system used to orient the station by the longitudinalem-axis with respect to the oncoming ion flux;

Panels with sensors for studying micrometeoretic particles.

On the outside the transfer compartment together with the equipment installed in it is closed with a vacuum shield thermal insulation to insure the required thermal regime.

The operating compartment comprises two cylindrical zones connected by a conical section. The diameter of the zone of the small cylinder is 2.9 meters, the length is 3.8 meters, the diameter of the large cylinder zone is 4.15 meters, and the length is 4.1 meters. The conical section connecting the cylinders has a length of 1.2 meters.

Inside the working compartment along its entire length on the left and right sides there are frames with apparatus and equipment. Thus, access is insured in practice to any module. The instruments and cable network installed on the frames are covered by removable interior panels.

A great deal of attention has been given to the decorative materials used to finish the manned compartments. High requirements of fireproofness, nontoxicity and formation of texture were imposed on them. In order to facilitate the orientation of the crew under conditions of weightlessness, each surface of the compartment has its own color: the front and rear are light grey, one side is apple green, the other is light yellow; the bottom of the station (the floor) is dark grey.

In the small diameter zone there is a table for eating. A replaceable tank with drinking water is attached to the table. The food heating units are located nearby. The primary water storage is in tanks aft on the starboard and port sides.

The food storage is in refrigerators installed symmetrically starboard and port (in the center of the large diameter zone).

The cosmonauts spend their spare time in the small diameter zone. A tape recorder and cassettes with recordings made by the request of each member of the crew, a library, a sketch album and other objects required for passing leisure time are stored there. Sleeping areas are located port and starboard of the operating compartment in the large diameter zone. If they so desire the cosmonauts can also sleep on bunks installed in the orbital compartment of the transport space ship.

The sanitary-hygienic unit is aft. It is separated from the rest of the work compartment and has forced ventilation. The surface of the sanitation compartment panels is finished in washable material. The set of devices for physical exercises and medical research is located in the conical part of the working section.

The general illumination is distributed so as to create the required working illumination for each control station and also the general illumination for the living quarters. Television lights have been supplied for the television reporting. The gyroscopic instruments of the navigation and motion control system are installed in the vicinity of the forward end of the work compartment on a rigid frame.

The manual control and monitoring media of the basic systems and the scientific apparatus of the station are at seven stations.

Station No 1 is the central control station of the Salyut. The control of the basic onboard systems and, in part, the scientific apparatus is concentrated here. This station is located in the lower part of the work compartment (in the small-diameter zone). The station is equipped with two chairs on which two astronauts can operate simultaneously. The astronauts' panels, the control arm for the orientation and navigation, the optical viewers of the orientation system and ports are located there.

Station No 2 (astropost) is located in the work compartment (in the small-diameter zone). It is designed for working out the manual astroorientation and astronavigation. At the station there are a panel, a control handle for the orientation of the Salyut, means of holding the cosmonaut in the work position, and a port.

Station No 3 designed to control the scientific apparatus is located in the central part of the compartment (in the large-diameter zone). Here, provision has been made for control panels for the equipment and a port.

Station No 4 also serves to control the scientific apparatus and, in addition, it is used for medical research. The equipment of the station is below, in the conical part of the work compartment. The control panels for the scientific apparatus, the port, the chair and the medical research equipment are located there.

Station No 5 is designed to control the Orion stellar telescope. Its control panels, the port, the sight and the arm for guiding the modules of the stellar telescope to the given star are located in the transfer compartment, above.

Station No 6 (astropost) is analogous with respect to purpose and composition to station No 2, but in contrast to station No 2 it has a chair and is located in a bay which if necessary can be converted by means of a shutter into an isolated "warm room." All of the equipment of station No 6 is located in the working compartment on the port side (in the small-diameter zone).

Station No 7 is used to control the scientific apparatus for studying the space about the Earth. Its controlppanels for the equipment, port and means of holding the astronauts are on the starboard side in the bay symmetric to the bay of station No 6.

A large part of the outside surface of the small-diameter working compartment is covered with the radiators of the heat control system. A small zone at the bottom (along the generatrix of the cylindrical section) constitutes an exception. A number of ports, sensors and optical viewers of the orientation and motion control system are located there.

The outside cylindrical section (large diameeer) and conical part of the work compartment are covered with a heat-protective shield which is used for protection from aerodynamic heating in the section for inserting the station into orbit, and itddecreases the leakage of heat from the saation in orbital flight.

The antennas of the radio complex of the station and the panels with sensors for recording micrometeoritic fluxes are installed outside the working compartment.

The apparatus compartment is basically used for fuel tanks with the working medium, the correction engines and also the system for controlling the orientation engines.

On the outside surface of the apparatus compartment there are two solar cell panels, antennas, one of the external television cameras, ion sensors and certain scientific instruments.

Onboard Systems of the Salyut Station

System for Controlling the Onboard Equipment of the Station

The system for controlling the onboard equipment provides for the interaction of the onboard systems, the assemblies, structural elements and scientific apparatus and also control of them from the station panels and the Earth. For control of the station as a whole, automated systems and logical-programmed circuits are used which permit the crew to be freed of a number of control functions. It has given the crew the possibility of concentrating their efforts on performing research work.

The flight control of the orbital module in the unmanned mode and also the station flight during rest of all members of the crew was provided for completely from the ground. In these stages the entire set of automation and remote control of the control system went into operation.

The control system for the onboard complex performs a number of important functions including the programmed-time control of the operation of the onboard systems, the storage of the algorithm for their functioning, gathering and logical processing of information about the state of the systems and correction of the algorithm for their functioning, the representation of the information about the operation of the onboard systems and the executed programs on the panels of the astronauts, the electrical coupling of the systems, the distribution of electric power with respect to time and protection from short circuits.

When controlling from the ground, the commands come onboard via the command line of the radio complex where they are processed and converted into the form necessary for inclusion of the power supply and controlling the onboard systems. Logical automated units and time-program circuits are used as the basic devices for processingaand converting the control instructions onboard the station. These are primarily small computers the memory of which includes a number of standard flight operation control programs.

The logical automation joins the onboard systems and scientific apparatus to the panels and instruments of the power automation into a single complex. The algorithm for functioning of the onboard systems contains a number of standard programs the execution of which is realized on request from the corresponding logical automaton. With an increase in flexibility and operativeness of control, several of the standard programs can be processed simultaneously.

Manual control of the flight of the station in the manned mode and the performance of scientific experiments are both realized by the crew concentrated at the seven stations. For convenience and operativeness of manual control the cosmonauts can use the standard automated control programs, realizing when necessary monitoring and correction of the operation of the automated circuit.

The onboard computer permits the station crew to solve navigational problems and process the data required for the performance of experiments and the basic operations of the flight program.

The basic work area of the commander and the flight engineer is the central control post of the station. From this station they control the Salyut as a whole and coordinate the work of the special-purpose stations. At the central control station all information is received about the operation of the onboard systems, including warning and especially important information which runs continuously and the duty information coming in by request from the central control station. The central control post of the orbital station is equipped with the primary control panel, the control panel for the life support and thermal regulation systems and the control panel for the navigational apparatus.

The primary panel comprises the instrument blocks and two command signal units. On the instrument block there are devices for monitoring the execution of automated programs, obtaining the required information about the operation of the basic systems of the station and also the instruments for navigational calculations. Key switches, electrically lighted signal displays, the navigation indicator of the Globus, onboard chronometers, cathode ray display and the control elements for the radio communications system are mounted on the board.

With the help of the navigation indicator which is a complicated electromechanical programmed device, the crew can determine the location of the station at each given point in time, the number of orbits made by the station, the time of entry and exit from the Earth's shadow, and the possibility of radio communications with the ground stations.

In the autbmated control mode, the cosmonauts follow the processing of thepprogram by the control indicator which is a mnemonic circuit. It reflects the execution of the control operations and their content. The electrically lit signal display of the instrument board communicates the most important information about the operation of the station systems and it also informs the cosmonaut about the necessity for intervention in their operation.

The command signal units are used to output the basic part of the commands and receive information about their use. In order to decrease the number of keys and for greater convenience of operation, the command signal units are executed as a matrix circuit. Each command is generated by pressing two keys.

On the control panel there is a panel of especially important commands (for example, switching the engine on and off) and also units for remowee adjustment of a number of instruments of the station orientation and navigation system and other systems.

In addition to the central control post, the station is equipped with six special-purpose control stations outfitted with control panels for the corresponding equipment. The special-purpose panels provide for controlling the scientific research experiments. By using them, the station crew controls the apparatus of the orientation and navigation system. It performs medical and biological research, and so on. From all of the panels it is possible to control the telemetric devices for recording the results of the experiments performed, the communications media, and the lighting.

For coordination of operations, the special purpose stations are connected with the central station and among each other by an internal talk circuit. The radio communications with the ground command-measuring complex are set up by commands from the central control post. When performing experiments connected with changing the position of the station in space, manual control of the orientation and navigation system can be transferred to the special-purpose stations by command from the central control station.

The experiments performed under the conditions of space flight on the Salyut station to investigate man as an element of the control system will permit determination of ithe paths of further improvement of the manual and automated control systems and efficient distribution of functions between them for future manned space stations.

Motion Control and Orientation and Navigation Systems

The motion control and orientation and navigation system jointly with the servoelements (the orientation motors) and the correction motor is designed for solving a number of problems. This system provides for automated and manual orientation of the station in the orbital coordinate system and also rotation and orientation of the station axes on given points of the celestial sphere. It is used also for automated and manual orientation of the station by the plane of the solar cells toward the Sun with subsequent twisting of the station around the axis perpendicular to the plane of the cells. In addition, the system is used for automated stabilization of the station when operating the power plant, for shutting down the engines after achieving the given magnitude of the velocity increment (when correcting the station orbit), to control the processes of rendezvous and docking of the transport spacecraft with the station.

Automated control is used to perform dynamic operations in the absence of the crew onboard the station and also to facilitate the work of the crew. Manual control expands the possibilities of orienting the station and increases the reliability of executing the flight program.

The motion control and orientation system includes the following apparatus;

Ion orientation sensors by the velocity vector in which the ion flux is received by four ion traps located symmetrically with respect to the longitudinal axis of the station (for deviation of the longitudinal axis from the direction of the velocity vector at the sensor output, control signals are formed which are proportional to the current difference of the corresponding ion traps);

The infrared local vertical plotter, the operating principle of which is based on using infrared emission of the edge of the terrestrial disc and the atmosphere;

The sensor for orientation on the Sun having a central field af view and four lateral survey zones for detecting the Sun and reduction of its image to the central field of view;

The angular velocity sensors with respect to three mutually perpendicular directions;

The free gyroscope module which provides for programmed rotation of the station with respect to the initial directions of orientation;

The longitudinal acceleration integrator for shutting down the correction power plant after obtaining the given velocity increment;

The stabilization unit serving for amplification and conversion of the gyroscopic sensor signals;

The module for switching the orientation engines on which shapes the control signals to switch on the corresponding orientation engines.

The set of rendezvous radar equipment insuring (jointly with the transport ship apparatus) measurements of the angular position, relative velocity and distance between the ship and the orbital module of the station during the rendezvous process in orbit.

The stabilization of the station during operation of the basic correction engine is realized by the orientation engines, and during operation of the duplicate engine, it is realized by a special nozzle system of the correction ppwer plant. The control of these nozzles is exercised by the steering engines on command from the stabilization module.

In order to guide the optical instruments to the required section of the celestial sphere, the orientation and control system provides for rotation of the station with a constant angular velocity with respect to the direction of the Sun (with the corresponding angular setting of the solar sensor) until the appearance of the required star in the field of view of the instrument.

One of the most important modes is the rendezvous mode and subsequent docking of the transport spacecraft with the orbital module of the station. The rendezvous to a distance on the order of 15-30 km is carried out by changing orbit of the orbital module and the transport ship. Then mutual rendezvous is realized by the transport ship (which is the active object) using the radar equipmant installed onboard and the response apparatus of the orbital module.

The transport ship using radio signals from the orbital module is oriented along the line of sight. Then by radio signals from the transport ship, the orbital module of the station is oriented. After this, the parameters of their mutual motion begin to be measured. The parameeers of motion are processed in the rendezvous control module of the transport ship. Here, the times of inclusion and exclusion of its correction engine to insure the required rendezvous speed are determined.

The orbital module of the station during rendezvous is automatically oriented by its longitudinal axis along the line of sight. Beginning with a distance on the order of 400 meters and to the time of mechanical docking of the objects, the transport ship is not rotated by large angles, and its correction engine is not switched on; its trajectory of motion is corrected by using the low-thrust coordinate engines.

The manual control circuit permits the crew to orient the station with respect to the Earth, the Moon and the Sun, individual stars and constellations.

For this purpose, the required magnitudes of the angular velocity with respect to station axes are given. The angles of rotation are determined by the crew either with respect to the external reference points observed through the optical viewing instruments or by the displays of the station position sensors.

The manual orientation of the station is realized from the main and auxiliary posts equipped with optical orientation instruments and control levers. The orientation control arm provides control over three channels, and it has three degrees of freedom respectively. It permits the angular velocities to be assigned to the station to a few degrees per second. The precision mode of orientation with minimum angular velocities is possible.

The optical orbital and solar radiation instrument is a set of one "central" optical system and eight "peripheral" systems. The Earth's horizon is observed in eight individual zones which permits orientation of the station with respect to the local vertical in a broad range of altitudes and from any initial position. A special grid has been provided to facilitate orientation. In order to decrease the image brightness during orientation on the Sun, dense filters are used in the instrument.

The motion control and orientation system can function in a number of automatic and manual control modes among which is the orientation mode of the solar cells on the Sun. By signals from the solar orientation sensor, the viewing axis of which is set perpendicular to the plane of the solar cells, the station is rotated. In this case the image of the Sun is brought to the center of the field of view of the instrument. Then in order to insure gyroscopic stabilization of the system, it is "twisted" (relative to the direction of the Sun) with an angular velocity of about three degrees/sec. In order to compensate for the effect of the disturbing moments, the direction of the axis of rotation of thessystem is periodically corrected until it is coincident with the direction of the Sun.

The automated orbital triaxial orientation of the station is carried out by signals from the infrared vertical plotter (over two control channels -- pitch and bank) and the ion sensor signals with respect to the heading channel. Provision has also been made for the possibility of uniaxial orientation with respect to the velocity vector using the ion sensors.

From the position of orbital orientation the station can be brought to any given position in space. For this purpose, at the required point in time the gyroscopes are unlocked and the corresponding programmed rotations are made. The control system maintains the orientation of the station corresponding to the time of completion of the programmed rotations.

The onboard stellar globus is used for orientation of the station with respect to the stars during manual control. It is a sphere with the configurations of the constellations plotted on it. The stars (to fifth magnitude) are simulated in the form of points having different relative brightness.

The stellar sphere is placed on a gimbal which makes it possible to trace the rotations of the station with respect to the stars and also to find the optimal trajectory of rotation of the station toward the required constellation.

Servoelement System

The system of servoelements is functionally part of the motion control and orientation system. It is designed to create control moments to orient and stabilize the station.

The control moments are created by the liquid-fuel rocket orientation micromotors operating on two-component fuel. The fuel reserve and the reserve capacity of the system are insured by the performance of dynamic operations on a prolonged orbital flight. In order to improve the operating reliability of the system, redundancy of the most responsible elements is provided.

The system of servoelements comprises a pneumohydraulic system of the displacement type, reactive orientation micromotors and the inclusion and monitoring units.

The pneumohydraulic system is designed for storing the fuel components and feeding them under pressure to the motors. It includes the tanks with high pressure gas, the gas reduction and feed units, the tanks with the components, and the sensors for monitoring the temperature, pressure and fuel consumption.

The jet microengines are used to create the thrust over three station control channels -- pitch, yaw and bank. The system includes the basic and redundant sets of motors.

The blocks for inclusion and monitoring include the defined motors on command from the control system, they monitor their operation and also select the primary or redundant set of motors.

Electric Power Supply System

The united electric power supply system insures a DC and AC power supply for the station. It includes the primary sources of electric power -- the solar cell and the electrochemical energy storage elements (storage batteries), the automated electric control and remote control monitoring units, and the DC-AC converters.

During autonomous flight of the orbital module of the station, its solar cells are used; after docking of the module with the transport spacecraft, the solar cells of the spacecraft are connected also to the system.

The necessity for orientation of the solar cell panels rigidly fixed to the hull of the station on the Sun is taken into account in the flight program, and it implies the introduction of special orientation modes (the "twisting" modes). On each orbit about 40 percent of the time the orbital station is in the shadow of the Earth; in addition, the nature of the electric power consumption on the station differs by alternation of the relatively small load of the duty regime and the large load during the orientation sessions, the operation of the scientific apparatus, communications equipment, television and telemetric devices.

The role of the highly maneuverable peak source of current in the system is played by the buffered cadmium-nickel storage battery which has rigid volt-ampere characteristics and operates jointly with the solar cells in the charge-discharge mode (buffer mode). The storage battery creates favorable equalizing conditions for the operation of the onboard electrical equipment. It also performs the function of a reserve source of electric power in the case of a temporary disturbance of the normal operation of the primary generator.

The joint operation of the solar cells and the buffered cells is provided for by an electric automation system which performs the functions of protecting the storage batteries from remaining for prolonged periods at the critical points (overcharging, overdischarging), monitoring of the electric power supply system parameters, and switching of the electric power supply system to the Earth control mode or the pilot panel control mode and switching to the parallel operation of the electric power supply system of the basic module of the station and transport aircraft.

In the circuit for protection from overcharging, the basic signal to disconnect the storage battery from the generator is given by the maximum voltage sensor. If for any reason the protect has not responded by the basic sensor signal, the battery disconnects on signal from the contact manometers mounted in the individual storage batteries and responding at a defined pressure in them. In the system for protection from overcharging generating the command to disconnect the load and charge the storage battery, two minimum voltage sensors adjusted with a potential difference of 1 volt are used as the sensitive elements. The second sensor responds if the first stage protect has for some reason failed to stop further discharge of the battery.

The dynamic level of charging the buffered storage battery is controlled using a special ampere-hour counter located on the cosmonaut panel and also over the telemetry channels on the Earth and at the flight control center. In addition, the voltages on the busses of the onboard network, the load current for supplying the electric power users, the solar cell current and the position of the electric automation elements are monitored constantly.

The joint operation of the electric power supply systems of the orbital module of the station and the transport ship has certain characteristic features. After docking, both electric power supply systems are combined. The buffered transport battery of the transport craft is kept in the charged state, and its solar cell is connected in parallel to the solar cell of the orbital module. Thus, the apparatus of the craft and the station receives electric power from a common electric power supply system.

In the case of powerful long sessions, provision has been made for the connection of a reserve storage battery to the busses of the basic buffer battery. On completion of the session, the reserve storage battery is charged and is in the stored regime until the next session with a large consumption of electric power.

In order to supply the scientific equipment with electric power, an autonomous electric power supply system has been installed on the orbital station. The primary feature of this system is the presence of a static voltage stabilizer. This voltage stabilizer insures a highly stable feed voltage for the scientific equipment with deviation from the rated value within the limits of no more than 1.5 percent. The primary current source in this system is one of the sections of the solar cell. After charging the buffered battery of the scientific equipment, this section is connected to the basic electric power supply system.

Radio Equipment

The onboard radio equipment of the station jointly with the command-measuring devices takes trajectory measurements, transmits control instructions and telemetric information, it maintains two-way telephone-telegraph communications, it transmits television images and provides precision gridding of the onboard time to ground time.

The trajectory measurements are necessary for organization of the communications sessions, orbit correction, realization of long-range rendezvous of the orbital module with the transport ship and also for coordinating the results of the scientific research with them. The transmission of the control commands from the ground command-measuring complex is a unique method of controlling the operation of the equipment during absence of the crew from the station.

The onboard radio equipment is a means of transmitting the telemetric information about the operation of the onboard systems and the results of a number of scientific research projects to the Earth. It participates in providing two-way telephone and telegraph communications with the Earth on shortwave and ultrashortwave and also internal telephone communications between the station compartments. The onboard apparatus for radio communications on the Salyut station transmits special time marks to the Earth for exact coordination of the onboard time with the ground time.

The orbital parameters of the Salyut station are measured by means of two onboard transponders operating on different wavelengths. As a result of this, the orbital parameters of the orbital module and the transport aircraft can be measured simultaneously. The operating reliability of the radio system is improved and the measurement errors caused by refraction and delay of the radio waves when they pass through the ionosphere are decreased.

By using the radio system at various ground stations, the slant range, the radial velocity and angular position of the station with respect to the measuring points are determined. The measurement results are transmitted to the coordinating computation center which processes the incoming information.

The slant range is measured by the method of relaying the interrogation range signal through the station apparatus. The measurement of the doppler shifts of the carrier frequencies of the transmitters at the ground stations and onboard the orbital station insures determination of the radial velocity.

The angular position of the station is determined using the goniometric system which is a component part of the antenna and receiving systems of the ground stations.

The systems and assemblies of the orbital station can be controlled from the Earth by using thecommand subsystems of the ground stations. The ground complex transmits command information to the orbital station in the form of single commands and numbers in binary code (so-called "sets"). The onboard equipment of the orbital station processes the received numbers in advance and decodes them.

In the orbital module of the station there are two multichannel radio telemetric systems. The redundant memories of the telemetric systems continuously recordsall of the incoming information which is later transmitted to the ground measuring stations when the orbital station is in the zone of radio contact with these points. During the process of communications sessions, direct transmission of the telementric information is also organized. The operative telemetric information is necessary to control the flight of the station from the Earth and to control the condition of the astronauts during the periods of location of the station outside the zone of radio visibility from the ground stations. For transmission of this information shortwave transmitting channels of the radio communications system are used.

The ultrashortwave and shortwave ranges in the radio communications system insure continuous two-way communications of the station crew with the ground saations for the entire flight. The ultrashortwave range is the most reliable form of communicationsin the orbital sections lying within the limits of direct radio contact with the ground stations. The shortwave range is used for longrange communications in the remaining sections of the orbit.

During the work of the crew at the Salyut station, the radio communications were maintained primarily by telephone. However, the telegraph regime of information transmission from onboard was provided for which permitted better use of the energy possibilities of the radio lines. For telephone communications, the astronauts used headphones which could be connected in various parts of theliving compartments. In addition, in the compartments there were speakers making it possible to transmit without the headphones. The radio communications system was controlled from central control stations and from the work locations of the crew.

The television system of the primary module of the saation provides for visual observation of the work of the crew from the ground, reporting by the astronauts and monitoring of the individual parameters of the onboard systems. The system has four transmitting cameras, two of which are inside the station and two outside. One of the inside cameras is fixed and transmits tha image of the two astronauts during their work at the control panel. The second inside camera is the reporting camera and permits transmission form any compartment of the station and also through the ports. It is equipped with an optical head with two interchangeable objectives — wide angle and telescopic.

Two of the external television cameras are designed for monitoring the orientation of the station in space during orbital flight. In the section for insertion into orbit by means of one of the external television cameras the process of separation of the primary module of the station from the booster rocket was monitored. The external cameras have optical heads with two interchangeable objectives and a set of neutral light filters the replacement of which is realized by control commands. All of the television cameras are equipped with the tubes of the vidicon type, and for standard arrangement of the 625 lines and 25 frames per second they have a resolution of 450 elements.

The television information is transmitted by external television cameras simultaneously to the video control units installed in the station control panel and on the ground. In addition, the telemetric parameters which characterize the state of the individual systems of the station are reproduced on the television screen of the control panel. The television camera is controlled both on command from the ground and directly by the astronauts from the control panels.

Heat Regulation Systems

The heat regulation system keeps the temperature of the working compartments, the apparatus and equipment of the orbital station and also the temperature and humidity of the air in the living compartments within the given limits. Simultaneously, it ventilates the living and onboard zones of the station including the compartments of the transport spacecraft after docking with the orbital unit.

In the living compartments of the station the air temperature is kept within the range of 15-25° C, and the humidity is within the limits of 20-80 percent, and the blowing rate is from 0.1 to 0.8 m/sec. The temperature level and the velocity of the air can be regulated as the crew desires.

The temperature of the majority of the elements of the unsealed compartment where the primary engine and the microengines of the orientation sytem with the systems for storage and transmission of the fuel components are located is stabilized within the given limits.

The heat regulation system of the station comprises two independent liquid loops -- the cooling loop and the heating loop. Each loop has the inside and outside mains split to an intermediate heat exchanger. The inside mains are filled with a nontoxic explosionproof and fireproof heat exchange agent of the antifreeze type, and the outside mains are filled with a heat exhhange agent based on organosilicon compound with a broad operating temperature range (from -70 to +100° C). The majority of hydraulic units of both loops were installed outside the station on special panels. For a number of units located inside (the fans, the devices for collecting condensate, and so on), provision was made for the possibility of repair and replacement in flight.

The excess heat is discharged when necessary from the sealed compartments of the radiator-cooler station the radiating surface of which is about

21 m^2. In order to increase the reliability of the heat regulation system and for protection from meteoretic punctures on a prolonged flight, the liquid circuits and a number of special protective elements are redundant.

The liquid temperature in the inside main of the cooling loop is regulated automatically within $\pm 2°$ C of the given rated value. The rated value is given from the onboard control panel permitting adjustment of the sensitive element of the regulator to three values of the temperature: 5, 7 and 9° C.

In the inside mean of the cooling loop special heat exchange elements are installed which are a combined cooler and condenser (cooling-drying apparatus) equipped with flow regulators. As a result, the gas temperature is maintained within the limits of 18-22 degrees at the exit from the apparatus. In the orbital module a total of six cooling-drying units have been installed of which three function simultaneously (the rest are in reserve). The fans of the cooling-drying apparatus jointly with the auxiliary circulating fans located in the living and instrument zones create a general air circulation in the sealed compartments of the station.

The inside main of the cooling loop is also used to thermostat the containers with the food stores (food refrigerators).

The heat and moisture exchange between the gas media of the compartments of the orbital module of the space station and the transport ship is realized during their joint flight by using a gas line system with circulating fans.

The heat required to compensate for the heat losses of the station into space is taken from the heater-radiator 6 m^2 in area which by design of the liquid ducts is analogous to a cooling radiator. From the heating radiator it goes to the intermediate heat exchanger, and from there to the heat exchange units included in the inside main of the heating loop. The regulator automatically maintains the liquid temperature in the inside main at the level of 21° C, regulating it within the limits of $\pm 3°$ C of the rated value. The manual control of the temperature regulator is possible by sending commands for complete closure or opening of the corresponding ducts of the regulator.

Life Support Complex

The life support of the crew onboard the station is provided by various systems. One of them is the system for maintaining the required gas composition in the atmosphere in the station compartments and absorption of odors and dust. In addition, this system equalizes the pressure between the station compartments and the transport ship after docking and compensates for possible gas leaks in case of partial loss of seal of the object.

The gas composition system is designed to maintain the barometric pressure within the limits of 760 to 960 mm Hg, the oxygen concentration at 160-260 mm Hg, the carbon dioxide gas at 0-9 mm Hg, and the harmful admixtures no higher than the limiting admissible concentrations.

In order to supply oxygen and remove carbon dioxide, the regenerator modules are used. Each module comprises two cartrides filled with highly active chemical. The air passes through the regeneration modules and as a result of the chemical reaction it is enriched with oxygen. The process of absorption of the carbon dioxide gas and harmful admixtures proceeds simultaneously.

The input lines of the cartrides are joined by a tubular collector to which the hose of the fan module is connected. The module comprises two centrifugal fans (the primary fan and the backup fan). Provision has beem made for automatic inclusion of the backup fan in case of failure of the primary one. All modules of the fans are interreplaceable, and they can be used in different combinations depending on the specific situation.

Inasmuch as in the operating process the regenerative material absorbed only part of the carbon dioxide generated by the crew, additional carbon dioxide absorption modules have been introduced into the system. The fans (the air ductsthe circulating fans) insure uniform mixing of the air in the living and instrument compartments of the station.

The harmful admixtures generated in the atmosphere by the materials and the products of the vital activity of the crew (ammonia, carbon monoxide, hydrogen sulfide, and so on) are obsorbed by the harmful impurity filter and they are also partially concentrated in the cooling-drying units of the heat regulation system.

The harmful impurity filter is a cylindrical cartridge filled with activated charcoal, chemical absorbent and catalyst with a fan unit connected to it. The dust filters contain a filtering material made of a mixture of shavings of organic material and chemical fiber. In order to improve the efficiency, four layers of filter paper were introduced also into the filter.

The composition of the air onboard the station is controlled by means of several gas analyzers at different points. This permits the crew to check the correctness of the instrument readings and the efficiency of ventilation between the living compartments. The instruments operate constantly; a warning signal is generated in case the admissible concentrations of oxygen and carbonddioxide are exceeded.

The partial pressure of the oxygen is determined by the electrochemical method; the partial pressure of carbon dioxide, by the thermal conductivity method. The absolute humidity is measured by an electrochemical heating sensor.

In order to perform certain operations (for example, evacuation of the transfer compartment or individual boxes for performing experiments), banks of purging tanks have been placed in the transfer compartment.

In order to equalize the pressurebetween the compartments and to release pressure from the compartments, a series of valves is used the operation of which is controlled visually by the instruments on the control panel and by the radio telemetric system data. The commands to include the especially responsible valves are blocked, their passage is possible only in the presence of a number of signs.

The life support media include systems for supplying the crew with food and water, the removal of the products of vital activity, prevention, diagnosis and treatment of possible diseases, the organization of labor activity and rest.

Onboard the station provision was made for eating food four times a day on working days: early breakfast, late breakfast, lunch and dinner. Three types of daily rations have been provided including various natural products (see the table).

Composition of food rations

Food intake	Ration No 1	Ration No 2	Ration No 3
Early breakfast	Sausages (entrecote, ham, meat paté) Borodino bread Chocolate Coffee with milk	Carbonate (ham, meat paté) Borodino bread Sweet (praline) Coffee with milk	Slided bacon (veal, liver paté, sausage meat) Borodino bread Candied fruit Coffee with milk
Late breakfast	Russian cheese Riga bread Candied fruit	Beef tongue (pork tongue, sausage meat) Riga bread Creamed cottage cheese with apple puree	Creamed cottage cheese Blackberry puree Honey cake
Lunch	Vobla [a Caspian fish like a roach] Sorrel soup Chicken (ham, meat paté) Table bread Prunes with nuts Blackberry juice	Vobla Borshch [beet and cabbage soup] Veal (liver paté, sausage) Table bread Capital cookies Blackberry juice	Vobla Kharcho [eating house]soup] Chicken (ham, meat paté) Table bread Prunes with nuts
Dinner	Pureed meat Table bread Honey cake	Pureed poultry Table bread Prunes	Poultry puree Borodino bread Russian cheese

The early breakfast contains 705-756 kilocalories, the late breakfast contains 600-700 kilocalories, lunch has 798-928 kilocalories, and dinner has 593-743 kilocalories. During the early breakfast, lunch and dinner the astronauts received one hot dish (soup, coffee) heated to the required temperature in the onboard heater.

The food rations were placed in cooling containers so that the process of preparation for eating is accelerated to the maximum. Eating takes place in a specially assigned area equipped with fittings facilitating this process under the conditions of weightlessness.

The system for supplying the crew with water was based on the water reserves stored in tanks of two types. According to the sanitation-hygienic requirements, the water was first preserved by the introduction of ionic silver and put in sterilized tanks. The potable water reserves were determined from calculating two liters of water per man per day (the actual consumption was on the average 1.2 liters per man per day. This corresponds to the water requirement also for flights of shorter duration).

In order to drink water each astronaut used a separate mouthpiece connected to a hose with a receiving tank into which the water came in measured portions. When the water reserves in one tank played out, the crew began to use water from the next. Their order of utilization (just as the food rations) was determined by the requirement of maintaining the overall centering of the station.

In order to remove the liquid and solid products of vital activity on the station, a sanitation unit was provided. Its operating principle was based on the transfer of particles of liquid excrements by the airflow into a special collector where they were divided between the liquid and gas phases. The solid excrements were gathered and stored in sealed tanks. The given system excludes the possibility of having harmful impurities and odors from the solid and liquid products of vital activity get into the atmosphere.

In order not to exceed the admissible dust and microbic spore level in the station compartments, special measures were taken during the flight preparation phase. In flight the crew periodically cleaned the interior of the compartment and atmosphere to remove dust by means of the onboard vacuum cleaner. A reserve of clothing was stored on the station for constant wearing and changeable sports clothing used when performing the physical exercises. For the morning toilet, dry and wet towels and napkins made of bactericidal tissue and impregnated with a weak disinfectant were used to clean the hands before eating and to wipe off with after performing physical exercises. Electric razors and safety razors and combs were used for the beard and hair.

The constant dosimetric control was realized by means of 2 radiometers in the operating compartment and a radiometer in the transport ship. The information about the magnitudes of the parameters recorded by these instruments reached the Earth during each communications session. In addition, each astronaut was equipped with an individual dosimetric kit offering the possibility of evaluating the total radiation dosage received by him on completion of the flight.

It is possible to judge the fitness for work of the astronauts according to observations during the television transmission sessions from onboard the station, by the radio conversations of the crew with the flight control center and by the execution of the flight missions. In addition, the state of health of the astronauts was monitored by the double recording during every 24 hours of the flight of some physiological indexes (electrical and mechanical activity of the heart and respiration), which were transmitted to the Earth over the telemetry channels.

In order to insure the arrival of this information the astronauts put on specially bent chest belts with the sensors installed. The apparatus permitted the recording and transmission of the physiological parameters of all the crew members during one communication session. The astronauts could be found at different points of the station in this case. Information transmission has not prevented their dynamic operation. Periodically (once every several days) the physiological parameters were measured and transmitted to the Earth after a dosed physical load.

For purposes of medical monitoring of the condition of the astronauts' health, the daily oral information was used transmitted by a standardized form. In this information the subjective evaluation by the astronauts of their health was reflected; there were some objective data, the nature of the physiological indications (appetite, sleep, and so on) and also the results of research using specialized equipment.

For prevention and treatment of possible diseases and acute functional disturbances in the medical equipment of the station provision was made for a pharmacy containing pharmacologic substances for various purposes: analgesics, cardiac stimulants, substances for normalizing the function of the intestinal track, antiseptics, bacteriostatics, hemostatics, sedatives, nervous-psychological tonics, radio protection, and so on. These pharmacies were available both in the orbital module and on the transport craft. During their stay in the station, the astronauts almost used no medicines at all.

In order to compensate for the deficiency of the usual physical load for the organism under the conditions of weightlessness, a unit was put on board the station for physical exercises. Special weighted suits were used. The test unit for the physical exercises is a treadmill (track) on which the astronauts are held by shock absorbers and a training suit insuring uniform distribution of the load.

The weight suits of the overall type with elastic elements (tension units) sewn in were used to create prolonged static loads on the skelatal-muscular system simulating the loads created by the Earth's gravity.

Docking Unit

The docking unit is designed for mechanical coupling of the transport ship to the orbital module after docking, sealing the joint and forming a passage between the ship and the orbital module by means of the hatches of the docking unit. Through this passage the astronauts can move freely from the transport ship into the orbital module and back, reducing the exit to outer space.

The docking unit comprises two parts placed on joined objects. One part is the active docking unit installed on the transport ship and equipped with machinery for realizing all the docking operations; the second unit is a passing docking unit installed on the orbital module of the station.

Each part of the docking unit is executed in the form of two basic, functionally and structurally autonomous units: the docking mechanism (on the active unit) and its corresponding part (on the passive unit); the docking frame with additional mechanisms located on it.

The docking mechanism on the active unit performs the basic functions with respect to joining the objects to contact of the docking frames. The corresponding, passive part of the docking mechanism is the receiving cone into which the pin of the docking mechanism enters during docking.

The docking frame is the sppporting part of the structural element of the unit. The docking mechanism, the hatch cover, the peripheral guide pins, the electric plugs, the sensors and peripheral frames, the seal and other elements are mounted on it.

The docking mechanism comprises the base of the stem, the electric drive with guides, the drive for withdrawing the detents, the two spring mechanisms and two side shock absorbers. The base is installed on the hatch cover through a ring which is attached to the base using four pyrobolts.

The docking mechanism provides for shock absorption of the collision of the object, their coupling and the drawing of the coupling elements to contact of the docking frames. During the rendezvous and docking process, the necessary signals are sent to the ship control system. The required information reaches the pilot control panel and the telemetric system.

The shock absorption of the collision is realized as a result of displacement of the stem of the docking mechanism and rocking of it with respect to the base on a ball hinge. When seating the stem, a spáral spring twists, and first the electromechanical brake turns, and then the friction brake. The energy of the shock absorber in the lateral direction during docking is absorbed by electromechanical brakes and spring mechanisms which return the system to the intial position after the shock. After captue of the head by the recess of the receiving cone and damping of the relative oscillations, the drive of the docking mechanism is connected to the drawing and equalization of the docking surfaces of the joined objects.

A mechanism for opening and sealing the cover is installed on the frame of the docking unit; inside the frame there are peripheral locks, a drive for them, guide elements, electric plugs, spring pushrods and sensors.

The docking seal is executed from two concentric rubber rings arranged on an active unit. Each of the eight peripheral locks comprises an active lock displaced with the help of an eccentric mechanism and a passive lock loaded with a spring. All of the pulleys on the eccentric shafts and the drive drum of the locks are joined by a flexible coupling permitting them to be rotated in both directions.

The mechanism for opening and sealing the cover comprises a system of catches connected by the thrust rods of their electric drives and the cover opening drive.

The undocking of the transport ship and the orbital module after closure of the covers is realized with the help of the drive which simultaneously withdraws all of the active catches from the coupling with the passive ones. Then the objects are drawn apart by means of four spring thrust rods. There is a backup pyrotechnical undocking system.

The execution of all operations with respect to docking and undocking is possible both in automatic mode and with control from the astronaut's panel. Provision has been made for the possibility of controlling the mechanisms of the passive unit from the transport ship and also transmission of commands for the execution of individual operations from the Earth with respect to the command radio line.

Protective Fairing

In order to protect the structural elements and instruments located outside the orbital module of the station from thermal and aerodynamic effects in the withdrawal section protective fairings are used.

The transfer compartment of the station with the docking unit, the panels of the solar batteries and the antennas is covered by the nose fairing. Part of the port of the working compartment is located under the upper blister fairings, and the optical instruments, under the lower blister fairings. The compartment for the scientific equipment, the three ports of the working compartment and the antenna of the ERA apparatus are coverdd by the individual covers.

All the fairings and covers are separated by means of pyrolocks. The time of separation of the fairings is selected considering that they have reached a remote zone far from populated areas. The structural design of the separation mechanism excludes the mechanical and thermal effect on the structural elements of the station and also it excludes the products of combustion (during response of the pyrotechnical media) from getting into the optical instruments and solar cells. The commands for control of the process of separating the ejected elements come from the booster rocket.

Transport Ship

In the experiment with the Salyut station, the role of the transport ship was played by one of the versions of the three-place Soyuz spacecraft. Just as all other spacecraft of this series, the given version of the Soyuz comprised an orbital compartment, the starting apparatus, the instrument compartment and the engine.

The orbital compartment was located in the forward section of the ship and communicates with the landing module by means of a sealed hatch. The compartment is designed for the cosmonauts to rest, the performance of scientific research and the placement of the useful load delivered by the transport ship. The orbital compartment is equipped with a docking unit insuring a mechanical coupling of the ship to the orbital module of the station after docking and the possibility of transfer of the astronauts from the ship to the module.

In addition to the delivered load, in the orbital compartment of the ship there are life support units, food products, a water supply, scientific movie and photographic eequipment, communications equipment, one of the television cameras and other equipment. The compartment has four ports for observing the surrounding space, taking pictures and for scientific research.

The basic purpose of the landing module is delivery of the crew and useful load received from onboard the orbital station to the Earth. Simultaneously, the landing module is the cabin of the astronauts in which the basic control elements for the ship are concentrated. In the landing module the crew is located in the section for putting the ship into orbit, for maneuvering in orbit, rendezvous and docking of the ship with the orbital unit of the station and launching to Earth.

The hull of the landing module is sealed and protected from the outside by heat resistant coating preventing it from heating in the launch section. The shape of the apparatus insures an aerodynamic lift of the required magnitude during flight in the atmosphere. By varying it, the flight in the launch section of the apparatus in the atmosphere is controlled. The use of the aerodynamic quality insures quite small magnitudes of the G-loads acting on the crew during launch (to 3-4 units). The control during launch significantly improves the accuracy of landing of the apparatus.

In the landing module there are three chairs for the cosmonauts, the control panel of the ship, the control system equipment, the life support equipment, thermal regulation, radio equipment, and so on. There are two parachute systems (the basic and reserve) in special containers.

The braking parachute of the basic system opens at an altitude of 9 km. Directly before landing, at an altitude of about 1 meter, the soft-landing blast braking engines are switched on as a result of which the landing velocity does not exceed 2-3 m/sec. A special automated machine controls the operation of the set of landing devices. For fast search after landing, the landing unit is equipped with radio systems giving it a direction-finding capacity in the segment of the descent using the parachute and after landing on the ground or in the water.

On the control panel of the landing module there are instruments for monitoring the systems and units of the craft, the navigational equipment, the television screen and the keyboard switches for controlling the onboard systems.

Along with the panel on a special port there is an optical viewer. On the port and starboard sides there are ports for visual observation, movie making and photography. On both sides of the central chair there are two control levers for controlling the craft: the right-hand one is for controlling the orientation around the center of mass, and the left-hand one, for variation of the linear velocity during maneuvering, rendezvous and docking.

The equipment of the ship provides for the possibility if necessary of completely autonomous flight and piloting of the craft without the participation of the ground command crew.

The instrument compartment is designed for the basic onboard apparatus and the propulsion unit of the spacecraft operating in orbital flight. In the sealed section of the instrument compartment conditions are maintained which are required for normal functioning of the apparatus. This compartment includes the following: the long-range radio communications and radio telemetry equipment, the orientation and the motion control system instruments with computers, the units for the heat regulating system, the power supply, and so on. In the unsealed section of the instrument compartment there is a liquid-fuel rocket power plant used for maneuvering in orbit, rendezvous with a docked object and also for descent of the craft to the Earth. The setup includes two engines (the primary engine and the reserve) with a thrust of 400 kg-force each. For orientation and displacement of the spacecraft when maneuvering there is a low-thrust control motor system.

On the outside surface of the instrument compartment there are the sensors for the orientation system and the primary antennas for the spacecraft systems. There are two solar cell panels which are opened after the spacecraft is in orbit.

In the insertion section the spacecraft is protected from the effect of aerodynamic and thermal loads by a nose shield which is ejected after passage through the dense layers of the atmosphere. The astronaut rescue system power plant is installed in the forward section of the nose cone. In case of an emergency during the active part of the trajectory, it separates the nose cone together with the descent apparatus from the booster rocket. In this case the descent apparatus emerges from the nose cone after separation from the booster rocket and descends on parachutes for a soft landing.

Onboard Spacecraft Systems

One of the basic systems is the system for orientation and control of the motion of the spacecraft performing a number of functions. It provides for orientation of the spacecraft in space, stabilization during operation of the engines and control when maneuvering, rendezvousing with the orbital module of the station and docking with it. The system can operate both in the automated mode and in the manual control model It includes a number of orientation sensors, the optical viewer-orientation unit of the astronaut, the gyroscopic instruments, the computing modules, the radiotechnical devices for search and measurement of the parameters of relative motion during rendezvous, the servomechanism complex and low-thrust motors.

The manual control of rendezvous of the transport spacecraft with the orbital module of the station is realized by the astronauts from the transport craft. In this case the orbital module, just as in the case of automatic docking, is oriented by the docking unit along the viewing line.

The information about the position and relative speed of the spacecraft and orbital module is received by the cosmonauts by means of the optical views and television system. The transmitting cameras of the television system have a variable field of view regulated by the crew. It permits variation of the image scale.

The relative speed of rendezvous of the spacecraft and the orbital module and the range between them are measured by the radio system used also for automatic rendezvous. The measurement results are disseminated to the velocity and range indicators.

For recognition of the orbital module of the station and determination of its relative orientation with respect to the spacecraft, optical and television indexes are established on it.

The power supply of the onboard equipment is realized by the centralized electric power supply system with solar cells having a useful area of 14 m^2. After docking of the spacecraft with the basic module the solar cells are used in the general electric power supply system of the orbital station.

The set of radiotechnical devices insures the determination of the orbital parameters of the spacecraft, the reception of commands from the Earth, two-way telephone and telegraph communications of the astronauts with the Earth in different wavelength bands, transmission of the television images of the situation in the spacecraft compartments and the external situation observed through the ports to the Earth.

The onboard television system has three cameras (one inside the spacecraft and two outside). They provide for the transmission of the television image of the normal standard. The multichannel radio telemetric systems permit transmission of a large volume of information. During flight of the spacecraft outside the line of sight of the ground receiving stations, the measurement data is accumulated in the onboard memories and transmitted to the Earth in the next radio communications session.

The set of life support systems includes the system for regeneration of the atmosphere, the food and water reserves, and the sanitation unit. Regeneration is insured by compounds of alkali metals which absorb carbon dioxide gas with simultaneous release of oxygen. Special filters absorb the harmful impurities.

The heat regulating system includes a liquid heat transfer circuit, an external radiator-emitter and a number of heat exchange units in the spacecraft compartments. Simultaneously with maintaining the temperature conditions, it realizes condensation of the excess moisture in the atmosphere of the inhabited compartments, collecting it in special moisture collectors. The temperature and moisture levels can be regulated by the astronauts.

When developing the structural design of the improved docking unit for the Soyuz transport spacecraft and the orbital module of the Salyut station, the previous experience in automatic docking of spacecraft of the Kosmos series and the experience in docking the Soyuz-4 and Soyuz-5 manned spacecraft was considered. After docking the transport spacecraft with the orbital unit of the station, a large number of onboard systems of the spacecraft are switched off and canned. The solar cells of the ship and its regulating system are connected to the corresponding systems of the orbital module.

The inhabited compartments of the spacecraft (the orbital compartment and descent apparatus) with a total volume of more than 9 m^3 after docking are connected to the general system of compartments of the station, and they are used for the crew to rest and perform certain types of operations.

Ground Tests and Preparation of the Salyut Station for Flight

Long before launching the Salyut station, a great deal of work began with respect to preparing the crew for performing the broad program of scientific research and experimentation. The training of the cosmonauts with respect to controlling the station and the transport spacecraft was organized. Ground services and the complex of specialized technical devices for flight control of the spacecraft and station were prepared.

During preparation for flight, the crew studied the structural design of the station and transport spacecraft, the operation of all units and onboard systems, they developed skills in controlling the station and spacecraft and the procedure to be followed in performing the scientific experiments onboard the station.

Before beginning flight testing of the Salyut station, a large volume of operations were performed with respect to ground processing of all its elements on experimental and test units and mockups.

The mockup for developing the general composition and relation of all the compartments and equipment of the station was done on a natural scale and was outfitted with properly scaled mockup models of the apparatus and equipment. The natural model was used to organize the efficient placement of the equipment, simulate the operating and television illumination, plan the interiors of the living compartments, and so on.

A specialized mockup was prepared for static and dynamic testing of the station compartments, checking the strength of the housing, the units for attachment of the equipment and other elements of the structure under the conditions of simulating static and dynamic loads which can occur in various stages of the flight.

The experimental engines permitted the development of all of their units, the filling of the engines with fuel components, and so on. During the "firing" tests, the operating life was checked, and the engine characteristics were more precisely defined.

Mockups were built for developing the life support system for the crew and the heat regulation system, including the natural-scale mockup of the station for complex testing in the barochamber with simulation of the factors of outer space. The all-around testing of all of the life support devices was carried out with the participation of examinees who lived in the isolated compartments of the mockup of the station for the same time and under the same conditions as provided for by the flight program.

The mockups for developing the ejected and opened elements of the station were used to test the dynamics of motion of the structural elements, determine the loads occurring during the operation, and so on.

The experimental device for developing the new docking unit offered the possibility of checking the process of docking the transport spacecraft with the orbital module of the station under various initial conditions of relative motion (linear and angular displacements, angular velocities). In addition, a number of experimental devices were built for developing the apparatus and units under ground conditions.

The training of the crews was carried out on trainers by means of which skills were developed in the control of the systems and dynamics of motion of the objects, and the interaction among the crew members was worked out. During these training sessions, the operating program for the individual members of the crew and the daily regime were more precisely defined.

Provision was made for a clear distribution of duties among the crew members.

During the process of preparing for flight the commander developed the technique for piloting the transport spacecraft and station during maneuvers and other dynamic operations. He coordinated the work of the entire crew and made decisions regarding operations in unforeseen situations.

The flight engineer controlled the state of the onboard systems, he provided proper maintenance and servicing for them, and together with the commander he participated in maneuvers and dynamic operations and on occurrence of unforeseen situations he prepared recommendations for decision-making.

The test engineer was involved with developing new instruments and onboard systems tested in flight, and he prepared the scientific apparatus for performing the experiments.

All of the crew members were trained for the performance of research onboard the station alone and jointly. Each of the crew members answered for the performance of a defined group of experiments. During his watch, each crew member maintained communications with the Earth, carried out mandatory obligations with respect to cleaning the station compartments, food preparation, and so on.

When necessary, all members of the crew were ready to perform operations connected with servicing the vitally important systems, insuring safety of the crew in flight and returning it to the Earth.

The clear distribution of the basic functions among the crew members, their comprehensive training, interchangeability when performing the most important operations -- all insured high fitness of the astronauts and efficiency of their operation in space and, in the final analysis, the successful execution of the flight program.

Flight control of the Salyut station, just as all ground surfaces and devices was assigned to the flight control center.

In operating practice the flight control center provided methods and means of control well-checked out and developed in advance during flights of the Soyuz series of spacecraft. Flight control of the manned spacecraft and stations is a complicated process realized jointly by the ground flight control center and the station crew using the set of ground and onboard technical devices.

During the process of flight control, a number of interrelated problems are solved. These are, above all, the prospective flight planning consisting in the development or assignments of the entire flight program with consideration of the specifically developed situation. Its purpose is the insurance of the greatest efficiency in carrying out the basic flight missions. During prospective planning, the required duration of the flight, the composition of the experiments, the volume and sequence of performing them, the distribution of the energy reserves with respect to flight stages, and so on are more precisely defined during prospective planning.

The next mission of the controleelements consists in operative flight planning which determines the operating program for the near future or the next orbit. A version of performing the next stage of the flight is selected and developed in detail. The operative planning provides for the distribution of all operations performed onboard the station by its crew or automated systems and and exact tying of them to the flight time. The basic characteristics of the crews and administration and methods of transmitting them are defined, and radiograms of the crew and radio commands generated from the Earth are prepared.

Simultaneously with the operative development of the flight plan, the insurance of technological operations necessary for flight control is planned. In particular, for example, the operation of the ground command-measuring complex is planned, the instructions are prepared for the tracking antenna systems, and so on.

During the flight control process, in practice the flight plans are executed. The control center ascends radio commands from the Earth to the onboard automation devices and the onboard systems. It transmits radiograms to the crew with recommendations, individual assignments and other necessary information. The center records and monitors all the control commands transmitted by the astronauts from the onboard panels, and it follows the movement and maneuvers ofthhe station or spacecraft performed directly by the commands of the crew or the servomechanisms of the automation devices on instructions from the Earth.

The various equipment of the station is switched on and off on command from the Earth or from the onboard panels, and its operating modes are selected. The control of the station and the spacecraft in performing the standard operations of the flight program always taking place identically with respect to specific algorithms is realized by means of the onboard program-time and logical automated units. These operations, include, for example, the maneuvers and orbital corrections of the spacecraft or station, some dynamic processes connected with the movement of the station around the center of mass, and so on. In this case, from the Earth or from the astronaut panel instructions are sent only for the beginning of such operations, and the necessary adjustment of the instruments is carried out. The broad utilization of the onboard automatic equipment for flight control of the Salyut station and the Soyuz transport spacecraft permitted significant simplification of the control process and improvement of its reliability.

In the manned flight stage the control functions are distributed among the control center and the station crew so that the crew is relieved to the maximum from the control operations. This permits it to concentrate the basic efforts on the performance of scientific experiments and research, to give more attention to direct servicing of the station systems. Prospective and operative planning and also the planning and insurance of technological operations are realized by the flight control center. Both the flight control control center personnel and the crew of cosmonauts in optimal cooperation for each specific case participate in the operations with respect to controlling the station and the spacecraft. Provision has been made for the possibility of completely autonomous control of the flight of the station and spacecraft and realized by the crew without the participation of ground personnel. In the given case, the onboard control units and the onboard systems for display and representation of the flight situation are used. The possibility of autonomous flight control can be used by the cosmonauts during flight outside the zone of radio visibility of the tracking stations or in case of disruption of radio communications with the Earth.

In the flight sections of the station without the crew, its control is realized by the flight control center.

During flight a large volume of information characterizing the flight situation constantly reaches the flight control center. This information is sent both from onboard the station or spacecraft and from the Earth -- by the various ground services. From onboard, for example, various reports come from the crew along with telemetric information on the state of the spacecraft or station, television images, acknowledgements of reception and execution of radio commands transmitted from the ground, and so on. The ground services transmit the trajectory measurement data, information about the radiation situation, the meteorological conditions with respect to the flight route and in the landing areas and so on to the center.

The information sent from onboard is received by an entire series of ground tracking stations located within the entire territory of the Soviet Union and also on ships of the USSR Academy of Sciences participating in studying outer space and located in the Atlantic Ocean during the space flight.

The information received from onboard is transmitted to the flight control center by ground communications channels or using the Molniya-1 communication satellites.

The telemetric information flows about the state and operation of the onboard systems and units of the station and spacecraft and also about the condition of the astronauts' health is decoded, processed and coordinated with the flight time at the flight control center. The primary information analysis is performed automatically on reception by means of high speed computers. This is determined by the correspondence of the parameters obtained to the normal or expected values. The results of analyzing the information in clear form are automatically depicted on special television screens, light displays, and indicators, and they are used by the flight center personnel for monitoring the course of the flight during the development of operative plans and during flight control.

The radio conversations with the crew during the entire space flight are carried out from the control center. During flight the station ouside the limits of radio visibility from the territory of the USSR in the zone of radio visibility of the ships of the USSR Academy of Sciences, the control center has the possibility of maintaining communications with the cosmonauts via the Molniya-1 communications satellite. The television images received from onboard are used during the communications sessions for direct observation of the operations of the crew and the processes taking place on the station. The magnetic recording of these images is used for subsequent analysis. The television observations of the cosmonauts help the doctors to evaluate their physical condition and facilitate medical monitoring. The movement of the television screen of the images of the Earth, the Sun or the Moon transmitted from the outside television cameras gives an idea of the orientation of the station in space or the direction and speed of its rotation.

The radio commands formulated at the control center are sent to the spacecraft or station from the transmitting command radio stations also located throughout the entire territory of the Soviet Union.

The broad network of tracking stations equipped with modern radio engineering systems and computer engineering combined by communication lines into one multifunctional complex insures the required redundance of the devices and the reliability of controlling the space flight.

The personnel of the flight control center for the Salyut station included, in addition to the flight control specialists, doctors for following the condition of health of the crew, scientists who coordinated the performance of the scientific research and experiments onboard the station, designers and specialists with respect to the onboard systems of the station who monitor their operation during flight, cosmonaut-pilots who have participated in planning the flight and in the control of it.

Just as the crew of the Salyut station, the personnel of the control center, preparing for the flight, have undergone a cycle of theoretical and practical exercises and training sessions. During these exercises, the apparatus of the control center investigated the structural design of the station and the transport spacecraft, and the methods of controlling them. During the training exercises, the interaction of the co-workers of control center with each other and with the crew of cosmonauts and the execution by each of them of their duties during the flight control process were developed.

Before launching the Salyut station into orbit, complex training exercises were carried out by the control center jointly with all ground services and calling on all the ground technical media providing for flight control. In the final stage of ground preparations, complex tests were also performed on the onboard devices and equipment during the process of which all of the basic flight regimes were developed. This was a type of general exercise indicating the complete readiness of the crews of cosmonauts and ground control personnel for flight, the readiness of the Salyut station, the transport spacecraft and the ground technical control devices.

After successful completion of the ground development, technical and organizational preparation of all the ground services, the Salyut orbital station was launched and inserted into Earth orbit. All of the control services and media began to work strictly by the chart matched with the flight program. The necessary corrections were made to this chart during operative more precise definition of the flight program.

Flight of the Salyut Orbital Scientific Station

Launching the Salyut

After successful launching on 19 April 1971, in accordance with the space research program, work was started in the space of the orbital scientific station Salyut. This was a new type of space apparatus permitting the complex scientific research under conditions of prolonged flight to be performed both automatically and with the human participation.

In the first stage flight was realized in the automated mode. After separation of the orbital module of the station from the last stage of the booster rocket, the panels of the solar cells opened automatically, and the onboard radio system antennas took up the operating position. On command from the ground, rotation of the orbital module which had started on separation from the rocket was halted.

The station was inserted into orbit close to the calculated one with the following parameters: maximum distance from the Earth's surface (in apogee) 222 km; minimum distance (in perigee) 200 km; orbital period 88.5 min; orbital inclination 51.6 degrees.

At the calculated time after launch, the orbit was corrected. For four days, from 19 to 23 April, the station flew in the automated mode in Earth orbit and completed 66 orbits around the Earth. The fitness of all systems of the station, the seal of its compartments and readiness to receive the crew onbbard were checked.

According to the telemetric information data obtained and processed by the coordination-computation center, the onboard systems, the units and scientific apparatus of Salyut were operating normally and were ready for performing experiments in space. On command from the ground, the station performed all operations provided for by the test program.

Docking the Orbital Module of the Salyut Station with the Soyuz-10 Transport Spacecraft

On 23 April 1971 at 0254 hours Moscow time, the Soyuz-10 transport spacecraft was put into Earth orbit with the crew onboard made up of the spacecraft commander, twice Hero of the Soviet Union, Astronaut-pilot of the USSR, Colonel Vladimir Aleksandrovich Shatalov, the flight engineer twice Hero of the Soviet Union astronaut-pilot of the USSR, Candidate of Technical Sciences Aleksay Stanislavovich Yeliseyev, test engineer Nikolay Nikolayevich Rukavishnikov.

The launch pursued the goal of joint experiments with the Salyut station, checking the improved onboard systems of the transport spacecraft, further development of the control, orientation and navigation and stabilization systems, and the performance of medical-biological research.

The initial apogee of the orbit (bythe conditions at 1200 Moscow time on 23 April) was 246 km; the perigee was 208 km, and the orbital time was 89 minutes; the inclination of orbit was 51.6 degrees.

After orientation of the spacecraft at 1355 hours on 23 April, a correction was made to the orbit by means of the manual control system. The Soyuz-10 spacecraft was put into a new orbit with parameters similar to the parameters of the orbit of the Salyut station.

Stable radio and television communications were maintained with the crew of the transport spacecraft. According to the report of spacecraft commander V. A. Shatalov, the astronauts felt good, and the onboard systems were operating normally. In the living compartments the conditions were being maintained similar to the Earth. The astronauts checked the onboard systems and did the necessary preparations for the spacecraft to perform joint experiments with the Salyut station.

On 24 April 1971, at 0447 Moscow time the Soyuz-10 transport spacecraft was docked with a Salyut orbital station. The process of docking the spacecraft is carried out in two steps. In the first step the spacecraft rendezvous with the station to a distance of 180 meters in the automated control mode. Then crew-controlled docking took place. In this stage all the control media for docking the transport spacecraft with the salyut station were checked out.

During the process of joint flight of the spacecraft and the orbital station lasting 5 hours and 30 minutes, a new docking system was tested. Joint experiments were performed, and complex checking of the improved onboard systems of the transport spacecraft was carried out. In the various flight modes, manual and automated systems for control, orientation, navigation and stabilization of the transport spacecraft and the orbital module of the station were developed in various flight regimes.

After performing the planned experiments, the crew separated and withdrew the transport spacecraft from the station. By using the external television cameras installed onboard the Soyuz-10, an image of the Salyut station and individual elements of the structural design were transmitted to the Earth.

The crew of the Soyuz-10 spacecraft performed the planned medical-biological studies of the effect of space flight factors on the human organism, and it also made a documented movie and took documented photographs.

At 25 April 1971, in 2 hours 40 minutes with respect to Moscow time the Soyuz-10 spacecraft completed a soft landing 120 km northwest of Karaganda.

The flight of the Soyuz-10 transport spacecraft permitted testing of the new docking module, in particular, improvement of its manual control.

The studies made in tested flight served as the basis for preparing a new expedition into space.

Flight of the Soyuz-11 Transport Spacecraft and Creation of the Salyut Manned Scientific Station

On 6 June 1971, at 0755 hours Moscow time, the Soyuz-11 transport spacecraft was launched with a crew made up of the ship commander Lieutenant Colonel Georgiy Timofeyevich Dobrovol'skiy, flight engineer, Hero of the Soviet Union, astronaut-pilot of the USSR Vladislav, Nikolayevich Volkov and test engineer Viktor Ivanovich Patsayev. The primary goals of the flight were docking the transport spacecraft with the Salyut orbital module, transfer of the crew to the scientific station and the performance of scientific-engineering studies onboard it for a prolonged period of time. At 1350 hours on 6 June the apogee of the Soyuz-11 orbit was 217 km, the perigee was 185 km, the rotation time was 88.3 min, and the inclination of the orbit was 51.6 degrees.

On 7 June after performing long-range rendezvous maneuvers on 797 turns of the Salyut station around the Earth the Soyuz-11 spacecraft rendezvoused and docked with it. The crew of the spacecraft checked the seal of the docking, the reliability of the connection of the electrical and hydraulic lines and completed its preparations for transfer to the Salyut orbital module. On the 801-st orbit of Salyut at 1045 hours Moscow time, the astronauts opened the covers of the inside hatch and entered the orbital module compartments. Thus the first all-term manned scientific station, Salyut, began to function.

After demothballing and checking the fitness of the onboard systems and scientific equipment of the station, the systems of the transport ship were mothballed, and the astronauts began to carry out the scientific and technical experimental program.

The labor and rest regime of the crew was developed during the process of training the astronauts. Every flight day of the orbital station, the crew worked on a defined scheme including constant and variable parts. Operations were performed daily with respect to servicing the stations. Part of the working day was devoted to carrying out variable individual assignments with respect to controlling the station and the scientific-technical experiments and research.

Provision was made for a defined distribution of sleep and watch times of a crew member and a duty schedule onboard the station. On the orbits with zones of radio visibility of the station with the ground command and measuring the stations within the territory of the USSR, as a rule, two astronauts were on duty, and sometimes all three. During these periods, the most important experiments and basic operations were performed. Thus, the flight control center could monitor the actions of the crew, make recommendations regarding the sequence of performing certain operations and assist in distressed situations.

The basic elements of the labor and rest regime of the crew of the orbital station were execution of the programmed assignments, physical exercise, eating hot food four times a day, personal time (leisure), eight hours of sleep and the morning toilet. The programmed assignments included the monitoring and servicing of the station and transport spacecraft, performance of experiments and the basics research operations, maintenance of communications, taking movies and photographs, television reporting, and so on. The complexes of physical exercises were performed twice a day one hour each on the "track [treadmill]" in special training suits. In addition, a light half-hour "walk" was taken before going to bed.

The astronauts devoted two to two and a half hours a day to personal time. They used this time for sight-seeing, for rest, observatinns, movies and photographs or for preparing for the next experiment. After six days of flight the crew was granted a rest day without experiments.

When developing tha labor and rest regime, special attention was given to the fact that the time actually spent by astronauts on one operation or another under conditions of weightlessness can differ significantly from the time spent on analogous operations under ground conditions. The personal time was specially introduced for organization of active rest by the astronauts during breaks between performing the basic experiments of the program.

Rigid observation of the labor and rest regime monitored by the flight control center promoted clear coordination of the work of the crew and ground supply groups and also successful activity of the astronauts under the conditions of prolonged stays in a state of weightlessness.

The radiotechnical ground control complex of the station received incoming information from onboard and transmitted the instructions and commands to the ship which were required for control. Inasmuch as this complex included various ground tracking stations and stations on the ships of the USSR Academy of Sciences, definite reserves and control reliability were guaranteed.

The powerful technical equipment of the ground measuring-command complex and the control center permitted operative and complete processing and analysis of the information arriving from onboard, timely and correct reaction to each variation of the flight situation, provision of the crew with data necessary to carry out the flight program, monitor its safety and take the necessary mearures on deviation of the course of the flight from normal.

The complex of means with which the control center was equipped included the high-speed computers, memories for storing information processed during flight, various displays, plotters and television displays for representing the information, internal communications lines, and so on.

The most complicated from the point of view of control were the sections of joint flight of the Soyuz transport spacecraft and the orbital Salyut station before docking and after undocking. During these segments, the personnel and technical media of the flight control center and the measuring-command complex were divided into three groups, one of which realized flight control of the Soyuz spacecraft, and the second, the flight of the orbital module, and the third permitted complex coordination of the control program, coordinating and matching the first two groups.

During its record 24-day flight, the crew performed a large volume of scientific research and a series of important technical experiments.

On completion of the test program on 29 June, the astronauts transferred the scientific materials from the station to the transport spacecraft, brought its systems out of mothballs, closed the hatches and proceeded with undocking. The processes of undocking and withdrawal of the spacecraft from the orbital module of the station were recorded on movie and photographic film.

On 30 June 1971, the Soyuz-11 spacecraft smoothly descended in the given region. Unfortunately, fate tragically took the lives of the heroic crew after completing the flight and scientific research programs. On the descent phase of the spacecraft 30 minutes before landing, a rapid drop in pressure in the landing module occurred as a result of the seal being broken. This led to sudden death of the astronauts. The names of the heroes who gave up their lives for the sake of all people of our planet will always remain in the history of humanity.

After undocking from the Soyuz-11 spacecraft, the orbital module of the Salyut station continued autonomous flight for 3.5 months during which the scientific research program was carried out, the fitness was checked, and the operating reserves of the systems during prolonged flight were checked out.

On 11 November 1971, the Salyut station ceased to exist above the Pacific Ocean.

RESULTS OF SCIENTIFIC RESEARCH AND EXPERIMENTS

Medical-Biological Research

One of the basic goals before the crew of the Salyut orbital station consisted in studying the effects of prolonged existence of man and other living organisms in space flight. The equipment of the station provided all possibilities necessary for this type of research. The high useful weight of the station and significant volumes of its internal compartments permitted various scientific equipment to be placed onboard the station for medical-biological research.

The selection of the basic problems of the physiological and biological experiments and observations was determined by the concepts existing in space biology and medicine of the phenomena which develop or can develop on various structural-functional levels of organization of living matter under the effect of a complex of space flight factors.

The crew of the Salyut station performed medical-biological studies with respect to two basic areas. The first is the study of the characteristic features of functioning of the human organism as the duration of the time spent under space flight conditions increases. The second is the study of the nature of development and certain aspects of vital activity of various biological objects.

Medical-Physiological Studies

When studying the characteristic features of functioning of the human organism in space flight, primary attention was given to studying the cardio-vascular system. This is connected with the fact that the functioning of the circulatory apparatus, just as other physiological systems of the organism is determined by the surrounding situation and, in particular, by the effect of the gravitational forces. In the absence of gravitational forces, quite rapid rearrangement of the hemodynamics is observed which appears, on the one hand, in the redistribution of the blood (an increase of inflow of blood into the upper half of the body) and, on the other hand, improvement of the re-action of the organism to the increased requirements imposed on the cardio-vascular system. The latter is exhibited primarily in the form of a reduction in economy of reaction of the circulatory apparatus to physical work and a reduction of the so-called orthostatic stability. By orthostatic stability physiologists mean the capacity of the cardiovascular system to insure the appropriate blood circulation of various organs under conditions where the man is in the vertical position. In this case, the inflow of blood to the heart and brain from the lower regions of the vascular system is made difficult inasmuch as under the effect of gravity the blood tries to accumulate in the lower half of the body. The physiological mechanisms providing for return of the blood to the heart from the lower regions must work with significant stress.

For the majority of people leading the ordinary way of life, the physiological mechanisms of regulating circulation are quite competent. In addition, for maintaining reliable mobility of the mentioned mechanisms regular exercising of them turns out to be necessary. If these mechanisms are not put into operation for a prolonged period, then the cardiovascular system "forgets how" adequately to react to the change in demands imposed on it. For example, when a man who has been in the horizontal position for a long period of time is brought to the vertical position, usually the syncope phenomena reserved which are caused by the fact that the blood circulation apparatus is in no position to insure with the necessary speed and sufficient degree the outflow of blood from the lower part of the body, its corresponding redistribution in the direction of the organs of the upper half of the body, in particular, the head.

As the experimental data demonstrated, the tendency toward the development of this type of phenomena occurred in the astronauts even after a relatively short time in a state of weightlessness.

The hypotheses beginning with the general concepts of the physiology of circulation pertaining to the probable characteristics of the heliodynamics under conditions of weightlessness were the theoretical basis for a significant part of the medical research performed during the first decade of manned flights. The results of this research especially obtained during the flight of the Soyuz-9 spacecraft demonstrated the correctness of the theoretical base adopted. Thus, when developing the program for medical-experimental research on the Salyut station primary attention was concentrated on studying the nature of circulation.

It is possible sufficiently completely to evaluate the state of the circulation function only for comprehensive consideration of its characteristic features. Above all, this is analysis of the parameters characterizing the cardiovascular system at rest. For this purpose, during flight of all members of the crew the electrical and mechanical phenomena connected with the heart and vessel activity were recorded periodically (electrocardiogram, kinetocardiogram, seismocardiogram, and so on). These data have permitted a phase analysis of the cardiac cycle reflecting the nature of occurrence of the excitation and contraction, its propagation with respect to the myocardium and also the mechanical phenomena caused by passage of the pulse wave and permitting evaluation of the state of the vascular wall and various characteristics of the arterial pressure.

The indicated physiological parameters were transmitted to the ground by the radiotelemetric system or they were stored by the onboard magnetic storage element. In order to record the parameters, amplify them and convert them to a form suitable for transmission to the Earth, apparatus of two types was available at the station. One of them could transmit a limited volume of information. The advantage of this apparatus consists in the fact that its servicing did not require significant expenditure of the crew's time. The information was transmitted to the ground daily by means of sensors attached to special belts which the astronauts put on in the time established by the program. These sensors recorded the electrocardiogram and the seismocardiogram and also the pneumogram (for estimating the respiratory function of the astronauts). The signals sent by the sensors permitted evaluation of the various functions of the cardiovascular system.

The other form of apparatus for recording and transmitting information to the Earth about the physiological parameters required simultaneous participation in the work of two astronauts: one in the role of the examinee and the other as the experimenter. This apparatus permitted recording of 22 physiological indexes, five each simultaneously.

The broadness of the spectrum of the characteristics taken using the apparatus of the second type insured that a large volume of information would be obtained and highly comprehensive evaluation of the function of the cardiovascular system. This apparatus had significantly broader possibilities with respect to comparison with the apparatus of the first type. However, as a result of significant labor consumption of performing the operations (the necessity for adjustment of the sensors, regulation of the signal by means of the onboard oscilloscope, and so on), the apparatus of the second type was used more rarely.

The complex evaluation of the characteristics permitted characterization of such vitally important functions as the excitability, the contraction of the cardiac muscles, the tonus of the vessels, the beat blood volume and the blood volume per minute, and so on. As a result, it is possible to compile a representation of how the hemodynamic system functions, whether forerunners of the improvement of the coordination in the activity of its various mechanisms insuring optimal system and organ blood circulation are appearing or not. During the process of analyzing the characteristics it is necessary to consider that the circulation apparatus has significant reserve possibilities gradually masking the small accumulated variations. Frequently it is possible to detect undesirable variations when recording various hemodynamic parameters in a state of rest only when these variations reach significant depth. The application of the functional tests facilitates the early diagnosis.

In clinical and expert practice there are a large number of functional tests, each of which has its advantages and disadvantages. In the Salyut station, two types of load samples were used. The first of them was the physical load, and the second is the effect of the artifically created dosed rarefaction on the lower half of the body. The physical load was created by conduction of the previously stipulated number of kneebends (under the conditions of dosed attraction "to the floor" by using rubber shock absorbers) for a defined time interval, for example, 30 kneebends a minute. Before the beginning of the cycle and after its completion by using a number of applied sensors, some of the physiological indexes were recorded which characterize the activity of the cardiovascular system. Such samples were recorded in two versions.

The samples of the first version were taken using an apparatus of the first type recording a smaller number of parameters, and they were performed approximately once every three or four days for each member of the crew. The data obtained characterized the electrical and mechanical activity of the myocardium.

The second version of the samples was recorded more rarely in connection with greater complexity of performing the operations. It provided information about the state of such parameters as the arterial pressure, the blood volume discharged by the heart with each beat and per minute, the propagation rate of the pulse wave with respect to certain main vessels, and so on.

The load sample of the second type based on the effect of dosed rarefaction is of interest under the conditions of space flight since it permits sufficiently close simulation of the reaction of the cardiovascular system to the transfer of the man to the regular position under the conditions of the Earth's gravity. In the state of weightlessness, the blood flow into the vascular channel of the legs and pelvis similar with respect to nature to the outflow created under the conditions of the effect of the gravitational force can be caused by the creation of rarefaction around the lower half of the body. For this purpose, a special device was placed on the station in the form of a "barrel" inside which it was possible to create rarefaction of the required magnitude.

The astronauts were loaded to the belt in this device and by using a microcompressor, a dosed rarefaction was created in it. The magnitude of the negative pressure was controlled by the altimeter on the panel. Before switching on the microcompressor during the effect of rarefaction (two rerefaction regimes lasting a total of 5 minutes were considered) and on its completion, the parameters of the cardiovascular system were recorded.

The information obtained in flight characterizing the activity of the cardiovascular system was compared with the data which were recorded for all members of the station crew in the preflight period. This type of analysis permitted establishment that the peculiarities of the blood circulation detected in space flight (in the state of rest) correspond to a stress of this function. In particular, for the commander and the test engineer, a tendency was observed toward an increase in frequency of the cardiac contractions, an increase in the mean arterial pressure, the propagation rate of the pulse wave before the initial part of the aorta and the brachial artery and an increase in the blood volume per minute. No such trend was observed for the flight engineer.

In addition, considering the clear manifestation of individual peculiarities and the absence of having the recorded indexes go beyond the limits of the norm characteristic of each of the astronauts, it is necessary to consider that during the flight time of the Salyut station for all members of the crew sufficient functional operation of the circulatory apparatus was retained. Among the astronauts a more expressed reaction was observed to the functional tests; however, no noticeable trend toward worsening of such reactions (in any case on the level significant for expert practice) as the flight time increased. This obviously is a still greater indication of retaining sufficient functional reserves of the cardiovascular system for several weeks of flight.

A comparison of the results obtained during flight with the ground experiment data permitted more precise definition of a number of concepts of the mechanisms of organization of the activity of the cardiovascular system under various external conditions. Some divergences were discovered between the proposed (on the basis of the model studies) and real phenomena.

Thus, the broad class of medical-physiological experiments significantly expanded the available concepts of the nature of the activity of the cardiovascular system under the conditions of space flight, and it permitted determination of the further direction of research in this field.

Along with the study of the characteristic features of the blood circulation, the crew members of the station also performed other studies of the nature of the vital activity. In particular, several times each the astronauts took blood samples during flights which were put in filters and stored in sealed containers with moisture absorbers.

In the blood samples returned to Earth, the sugar, urea and cholesterol contents were determined. The white blood picture and the number of leucocytes and thromobocytes per thousand erythrocytes were counted in smears. In all of the astronauts the increase in urea content in the blood was detected. This phenomenon obviously is connected with adjustment of the kidney functions which, as has been established considering other data, does not have a pathologic nature.

In the blood samples taken in the first week and at the beginning of the third week of flight, the sugar content was within the ordinary limits, and in the samples taken before the end of the flight, it had increased sharply. This fact can be explained by an increase in physical and emotional loads with the development of the phenomena of asthenization. The cholesterol content did not change during flight in any of the crew members. No significant changes were noted on the part of the cellular composition of the blood.

During flight the crew took some samples characterizing the other aspects of metabolism: samples with respect to studying the energy expenditures by measuring the gas metabolism, and samples with respect to studying the mineral saturation of the bony tissue. The results of the samples did not demonstrate a defined tendency toward variation of the indicated characteristics.

During flights the astronauts periodically measured the strength of the bones of the hands using dynamometers and also performed experiments to study the basic characteristics of the visual function: they investigated the sharpness of central vision, the light and contrast sensitivity, convergence and accomodation. The results obtained revealed the presence of some changes in the investigated functions which indicates the necessity for continuing such research.

The station crew performed a complex of research projects to study the relations between the organism of man in space flight for a prolonged period of time and the microflora surrounding him. For this purpose, before completion of the flight the air samples were taken and also smears from the inside surfaces of the inhabited compartments of the station and from the nasal cavity of the astronauts.

Sterile pads were used for the smears which after taking the sample were placed into sterile test tubes. The air samples were taken using an instrument in the form of a pump with a filter for precipitation of the microorganisms. After the return of these devices to Earth, the material contained in the filter and the pads was planted in special culture media. The subsequent bacteriological analysis demonstrated that at the end of the time the crew was on the station, the microorganism content in the air, on the surface of the interiors and in the nasal cavity of the astronauts increased. The variation in the spectrum of the microflora was established: an increase in hemolizing forms of microorganisms was observed.

The data obtained as a result of the experiment have significant theoretical and practical significance. They indicate the occurrence of changes in the macroorganism-microflora system under the effect of the complex of factors of space flight. It was noted that the changes which take place during space flight are significantly more expressed than is observed under analogous laboratory conditions.

Biological Experiments

The astronauts performed a significant volume of experimental work provided for by the medical-biological research program as a result of which many scientific data were obtained having great significance for further development of the manned space flights and enormous fundamental general biological significance.

During the process of medical-biological studies performed by the crew of the Salyut station, the nature of the occurrence of the fundamental life processes was studied (heredity, variability, individual development) on the different levels of the biological organization. Primary attention was, of course, given to the problems of gravitational biology, that is, the discovery of the degree of biological significance of the force of gravity which is a constant factor of the external environment in the entire period of evolution of life on the Earth. Space flights creates in this respect unique conditions inasmuch as in the ground laboratory it is theoretically impossible to eliminate the factor of the Earth's gravity. The absence of gravity permits in practice evaluation of its ecologic and, hence, its evolutionay significance for various biological species.

The studies of this type have great significance for understanding the mechanisms of the organization of motion of living matter and, possibly, they will promote further development of our concepts of the principles and motive forces of the most important biological phenomena such as cellular division and differentiation, individual adaptation to the environment and microevolution, and so on. Along with the general biological significance, the results of such studies must have also obvious practical significance. Obtaining the information about the peculiarities of the vital processes among model biological subjects, it is possible with defined approximation to extrapolate these data to analyze the processes occurring in the human organism in the cellular level.

In addition, the studies of the fundamental vital processes on an orbital station permit us to obtain the results which are important in solving the problems of the prospects of development of the life support systems of spacecraft and, in particular, the biological-technical systems.

The higher and lower plants, insects, amphibians and representatives of various protozoa were selected as the experimental subjects. The species selected for the experiments have been well studied in biochemical, physiological and certain other aspects. Among them there were representatives of such species for which the significance of gravity during the processes of vital activity is obvious (for example, the higher plants). Among certain subjects, a change of generations was observed during the flight period. Interesting data were obtained when performing the genetic, radio biological, embriological, biotechnical and certain other forms of biological experiments.

In order to perform one of the simplest experiments with respect to procedure, a module was placed onboard the station containing various forms of relatively simply organized biological subjects -- seeds, microorganisms, yeast, the lower plants, and so on. This module was found on the station from the time of its being launched, and before final departure of the crew it was dismantled and transferred to the descent module. All of the specimens were subjected to comprehensive careful analysis on Earth in order to determine the presence and expression of the individuals in the structure and function of the indicated organisms subjected for a long time to the effect of weightlessness by comparison with the control biological subjects found on Earth under other equal conditions in practice.

The second experiment was connected with studying the processes of differentiation of the organs of animals in the early (embrionic stages of development). The specific problem of this experiment was investigation of the nature of the occurrence of the process of basing of the organ of gravitational sensitivity in frogs. In order to solve this problem, two identical instruments were at the disposal of the astronauts, each of which was in the form of two insulated chambers. These chambers could be converted into communicating vessels by displacement of a special connecting rod. In one of the chambers there was a fixing solution, in the other chamber there was a frog egg fertilized recently before the launching of the Soyuz-11 spacecraft. Thus, the process of development of the tadpoles was completed primarily under the conditions of weightlessness. At the time when the process of development reached the required stage, the astronauts recorded this process by introducing a special fixing solution into the chamber with the offspring. The morphologic study of the material was carried out on the Earth.

The third experiment was stated in the classical subject of genetic research -- the fruit fly (the drosophilla). The problem of research included obtaining several generations of flies, the effect of weightlessness on which began or ended in different phases of their development. For this purpose, a small chamber was put on the station separated into several compartments. In the bulkheads between them there were small doors which opened from the outside through the passages of which the flies could fly into the next compartment. On the bottom of each compartment there was a nutrient medium. At the beginning of the experiment the insects were in one compartment. As the experiment progressed, after a defined time the astronauts opened the doors in one of the bulkheads, thus giving the flies the possibility of flying into the adjacent compartment. The doors in all the bulkheads were opened in the same fashion successively.

Thanks to this procedure, better conditions were insured for feeding the drosophilla. In addition, when analyzing the insects dying in the egg, pupa or larva stage, it was possible approximately to determine in what period of performing the experiment the life of the subject was ended. Consequently, the intensity of elimination (exclusion of the unknown) could be determined not only by the stages of ontogenesis (individual development), but also depending on the duration of the related species under the conditions of weightlessness. In parallel to the basic experiment in the ground laboratory a control experiment was performed repeating all of the external conditions (especially the temperature conditions which are very significant during the process of ontogenesis of drosophilla) which developed in the vicinity of the container with the fruit flies.

The experiment with respect to growing higher plants under the conditions of weightlessness was very interesting. As has already been mentioned, the higher plants belong to the biological subjects for the vital activity of which the Earth's gravitational force is unconditionally significant. In particular, the direction of their growth depends on the gravity vector. Accordingly, the propositions were stated that under the conditions of weightlessness, the higher plants will not in general develop. Along with the theoretical importance, the answer to this question also has great practical significance since the strategy of the development of operations in the field of creating artificial ecologic systems for the spacecraft of the future depends on it to a significant degree.

For the Salyut station, a device was developed insuring the possibility of growing the higher plants under onboard conditions using the method of hydroponics. The device is a cultivator including sources of artificial illumination, a tank with water and phytilli impregnated with saline mixture and placed in a thin rubber tank. A colony was placed on one end of each phytilli turned in the direction of the light source. By using a small pump which the astronauts drove by hand, a dosed amount of water was put into the rubber tanks daily. The water, rising along the phytilli and dissolving the salts contained in it was converted into the nutrient solution for the plants. Three types of seeds were placed in the pot: flax, cabbage and onions.

During the first day at the station the astronauts switched on the lighting for the cultivation pots and the movie camera for frame-by-frame photography of the plants and also they fed them the first portion of water. During the entire time of the stay at the station they accurately supplied the water, made visual observations and took photographs of the investigated plants. A ground experiment was conducted in parallel under controlled conditions.

Considering the fact that in order to obtain the required information a special processing of the material is required, its microscopic and biochemical analysis, the program of biological experiments was to a significant degree designed for performing conclusive operations in the postflight period. In connection with the fact that in the stage of descent, the biological material was subjected to the effect of rarefaction close to a vacuum and low temperatures, many of the data obtained when analyzing this material cannot be uniquely considered as evidence of the specific reaction to the effect of weightlessness and other factors characteristic of space flight (vibrations, cosmic radiation background, and so on). These results require confirmation in subsequent research.

In addition, the data obtained experimentally with growth of the high plants and confirmed by documents using movies, photographs and remote data, indicate the nature of the growth and development of the higher plants under the conditions of weightlessness. This extraordinarily important fact determines the further paths of research in the given region.

The conditions for performing the experiment on the Salyut station with respect to studying the effect of weightlessness on embryogenesis (the development of the offspring) of amphibians were somewhat worse because of the fact that the time of performing the experiment did not correspond to the period of activity of the seasonal fluctuations of the fertilization of the mammals. Accordingly, a significant part of the fish eggs turned out to be unfertilized. Although the results obtained permitted the conclusion to be drawn of the absence of a noticeable effect of weightlessness on the investigated phenomena.

Thus, although the program of biological research on the Salyut station was not completed in planned volume, all the experiments performed gave to a great extent important scientific results, the value of which can still be inherent further on comparison with the data of subsequent biological research.

Astrophysical and Physical Research

Extraatmospheric Studies of Cosmic and Gamma Radiation

The creation of the first manned orbital station marks both the beginning of the new phase of extraatmospheric studies of cosmic and gamma radiation and a number of other studies in the interest of science and the national economy. In order to clarify this statement it is sufficient, for example, to remember how the studies of cosmic radiation have developed.

The thickness of the Earth's atmosphere is approximately equivalent to the thickness of 10 meters of water. It is natural, therefore, that when studying cosmic radiation scientists have tried to eliminate or at least decrease the magnitude of this barrier insofar as possible.

The simplest way to achieve this is to set up special apparatus as high as possible above sea level on promontories on the Earth's surface, mountain tops, and so on. The discover of "cosmic radiation" -- the flow of descending "radiation" of extraterrestrial origin -- is connected with the ascent of apparatus on air balloons. It has been established that at a sufficient distance from the Earth's surface the intensity of this radiation rises.[1]

However, for direct investigation of the primary cosmic radiation, the altitude reached on air balloons and stratostats was insufficient. Only in recent years have high-altitude balloons begun to be used (unmanned) which take the apparatus to 30-40 km (at an altitude of 40 km there is still a layer of atmosphere above the instrument equivalent to about 2.5 cm of water).

Fifteen years ago, before the launching of the first Earth satellite, the cosmic radiation was studied usually only at altitudes of 25-30 km using balloon apparatus where the residual thickness of the atmosphere was still quite large (on the order of 10-15 cm of water). The study of the primary cosmic radiation under these conditions was difficult.

The use of high-altitude rockets to study the cosmic radiation also has its deficiencies and, primarily, it is the short term nature of the experiment.

The prominent place occupied by the study of cosmic radiation in the satellite research program, along with scientific interest has also been determined by other reasons. It was possible to solve an entire series of problems by comparatively simple procedure using apparatus which has no need for exact orientation in space, does not require powerful power supplies, is sufficiently light weight, and so on. At the same time, the development of extraatmospheric astronomy has imposed in general much higher requirements on the apparatus, and it has also forced astronomers to do a basic asjustment of many of the methods known to them.

The discovery of the Earth's radiation belts and also a number of other phenomena and peculiarities characteristic of the behavior of fast charged particles in the Earth's magnetosphere turned out to be unexpected. As for the planned studies of the primary cosmic radiation, satellitesshave still not completely justified the hopes placed in them. It is true that a number of

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[1] It is considered that the first convincing observations of this type were performed by V. Hess 60 years ago. The experiments which he performed demonstrated that the beginning of the increase in ionization intensity is fixed at an altitude of 1 km, and at an altitude of 4 km it becomes twice as much as near the Earth's surface.

interestinggresults have been obtained. Let us mention the observations of the nuclear component of the solar cosmic radiation, the study of particles with comparatively low energy, the study of variations and the primary steps of gamma astronomy[1]. However, the primary progress in the study of primary cosmic radiation (protrons, nuclei, electrons and positrons) has been achieved in the last decade by means of high-altitude balloons. During the first years after launching the satellites, of course, it was possible to install only comparatively simple apparatus on them successfully and with sufficient reliability. In order to obtain the modern data on the chemical and isotropic composition of cosmic radiation, its energy spectrum in the presence of high energies and so, improved equipment is necessary.

In addition, in order to solve certain modern problems in the field of the investigation of cosmic and gamma radiation scientists could not be satisfied even with large, heavy satellites equipped with the most improved modern apparatus. The necessity arose for the creation of orbital stations, large manned scientific laboratories in space which permit use of no only instruments for making studies but also cosmonaut observers. These stations also offer the possibility of delivering the observation results from the station to the Earth: photographic emulsion, oscillograms, and so on. Therefore, the Salyut orbital station symbolizes the beginning of a new phase in scientific research in the field of cosmic and gamma radiation.

The extraatmospheric studies of cosmic and gamma radiation on manned orbital stations are opening the possibility of stating new large and very interesting problems. The optical, submillimeter and x-ray astronomy has been developed further. The progress in x-ray astronomy completely based on balloons, rockets and satellites, the achievements of infrared (submillimeter) astronomy and the improvement of space engineering are providing the basis for significant improvement of the specific weight of the extraatmospheric astronomical studies on the modern level of the space program. The simultaneous development of extraatmospheric astrophysical studies and, in particular, the studies of cosmic and gamma radiation, is opening up great scientific prospects.

Studies of Stellar Spectra

As has already been established in recent years, the individual heavenly bodies are sources of powerful ultraviolet and x-radiation. This type of

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[1]Only charged particles of extraterrestrial origin and, in addition, having high energy (on the order of 1-10 megaelectron volts and more) have now become to be called cosmic radiation. However, from the physical point of view and in connection with the procedure used, the study of cosmic radiation is quite close to the study of the neutral particles of cosmic origin also having high energy (gamma radiation, neutrinos and neutrons). The cosmic gamma radiation plays a very important role. The recording of this radiation is the mission of gamma astronomy. For the indicated reasons, it is expedient to consider the astrophysics of cosmic radiation and gamma astronomy jointly.

object also includes the neutron stars, the existence of which was theoretically predicted more than 40 years ago and were discovered in recent years. The galaxies emitting waves in the x-ray range of several tens and hundreds of times greater energy than in the optical range are known.

The majority of the radiation of the small hot stars, some galaxies, the solar corona, and so on belongs to the shortwave vacuum and hard ultraviolet band.

The heavenly bodies with ultraviolet and x-radiation are qualitatively new subjects for astronomers. Their significance and role in the understanding of the universe and the phenomena occurring in it are difficult to overestimate. However, the study of these subjects is possible only by the methods of extra-atmospheric astronomy inasmuch as the terrestrial atmosphere is entirely opaque for radiation with wavelengths shorter than 3,000 Å (angstroms).

At the present time the majority of extraatmospheric observatories on artificial Earth satellites are automatic. In recent years they have been used to obtain a great deal of valuable scientific information both in the Soviet Union and abroad.

However, There are astronomical problems the resolution of which can be realized most effectively only under the conditions where the operation of a telescope in orbit is controlled directly by a man. With the appearance of heavy manned spacecraft and manned orbital stations, the possibility of such studies has expanded significantly.

The role of the cosmonaut is especially important in cases where the astronomical are made photographically. This is the most effective, at times irreplaceable means of obtaining mass information from broad expanses of the stellar sky, studying the extended selestial subjects, studying their fine structure with high angular resolution, and so on. The crew of the orbital station can provide for servicing and monitoring the work of the astronomical apparatus, periodic replacement of the cassettes with film, the delivery of the exposed film to the Earth in the transport craft.

The recognition of a subject in the sky and aiming a telescope at it are realized successfully by astronauts performing astronomical observations inasmuch as the telescope which is in a gimbal is outside the manned compartments of the station. The cosmonaut uses a remote control system to direct the telescope to the required object (the star, planet, and so on) and to insure subsequent exact automatic tracking (guiding) of the telescope on the observation subject.

Several versions of the solution of the stated problem are possible. One of them is based on using the obstacle telescopic sight installed opposite one of the ports of the station and the primary coarse guidance tracking system between the telescopic sight and the telescope mount.

The telescopic sight with a field of view of 5-6 degrees is installed in front of the ports and is attached to the supports directly to the hull of the ship. It can rotate in two mutually perpendicular directions.

The viewing angle of the telescopic sight within the limits of which the required star can be found and locked on is quite large -- on the order of 30 degrees.

The described principle of controlling the operation of the observatory by the astronaut was used as the basis for developing the Orion telescope installed on the orbital station Salyut and designed to obtain stars of individual spectrograms in the 2,000-3,800 Å range.

The basic element of the Orion telescope is the slitless stellar spectrograph which is a reflecting telescope of the Mersenne system with a light diameter of the large mirror of 280 mm, a small mirror diameter of 50 mm and an effective focal length of 1,400 mm. Opposite the parallel light beam reflected by the second mirror is the slitless spectroscope of the Wadsworth system. It uses a concave diffraction grating with a radius of curvature of 500 mm and dimensions of the crosshatched part of 50 × 55 mm. The strokes are applied to the aluminum layer covering the glass substrate. The number of rows is 1,200 per mm, the form of the rows is selected so that the maximum light concentration of about 2,600 Å is insured. The dispersion of thesspectrograph is 32 Å/mm, and the angular scale in the focal plane of the spectrograph camera is 2.5 Å.per mm. With accuracy of tracking a stellar magnitude of one regular minute, the spectral resolution of this spectrograph is about 5 Å (in the 2,600 Å range).

The spectrograms are recorded photographically on punched film 6 mm wide covered with UFSh-4 emulsion sensitive to vacuum ultraviolet beams.

Special attention was turned to insuring a high level of engineering development of the Orion set. Both mirrors of the telescope were made of pyroceramic, and their mounts were made of invar; the linear expansion coefficients of the materials used are almost identical within the limits of the expected temperature of the elements under natural conditions. The mirrors were installed in both mounts freely with a clearance between the mount and the mirror of 0.003-0.005 mm. The mirror coating was aluminum without protective layers.

The Orion spectrograph comprises three parts: the diffraction grating units, the cameras and the mechanism for expanding the spectrogram. The structural design of the diffraction grating unitswas developed in such a way as to realize adjustment and focusing of the entire spectrograph by shifting the diffraction grating with the camera attached. The focal plane of the camera is curvilinear. A plane parallel quartz plate 2 mm thick was installed in front of the film channel. It served as a light filter to eliminate the second order of the spectrum from the operating range (the band shorter than 1,900 Å). The camera was equipped with a cylindrical shutter operated from an electromagnet, a film tension and winding mechanism. The spectrograph was basically made of titanium alloys.

A biaxial stellar photoguide was attached to the telescope housing in parallel to its optical axis. It was designed to lock on a star and automatically track it (home on it with an accuracy of up to 10". The optical system of the photoguide is a lense (coated) guide, the field of view is 3 degrees, and the exit pupil diameter is 70 mm, the focal length is 450 mm.

The telescope is installed on a biaxial mount of the gimbal type and it is equipped with two electric drives which operate on a mismatch signal, coming from the stellar photoguide. The drives are made with partially sealed reduction gears with the application of special electric motors suitable for operation under the conditions of outer space.

An important component part of the Orion is the viewing system. It is designed for remote homing of the telescope module on the investigated target with an accuracy sufficient to insure lockon of the target by the stellar photoguide. The search for the target is made visually by the astronaut, and the telescope is sighted on it manually using key-type switches. The field of view of the telescope is 9 degrees, the angular resolution is 1, the viewing field is 35° × 35°. The entire module of the viewing system is installed inside the station in front of one of its ports.

In order to control the operation of all of the Orion systems, monitor the execution of the commands and the state of the set there is a special control panel. In the control panel there is also a programming unit which provides for an automated cycle of taking from one to five spectrograms for one star with different exposures.

The primary module of the telescope with the mounting and the photograph is installed outside the sealed compartment of the station in a special recess. On the outside the recess is covered with mats of vacuum-shielded thermal insulation which provides the necessary temperature regime of the instruments.

The crew of the Salyut orbital station received six spectrograms of the hot star Agena (β Centaur) on 18 June 1971, and three days later it received nine spectrograms of Vega (α Lyra). The duties were distributed as follows for this project: the ship commander G. T. Dobrovol'skiy controlled the orientation and navigation of the station, trying to keep it in the required position relative to the celestial coordinate system; the flight engineer. V. N. Volkov watched the onboard systems, and the test engineer V. I. Patsayev controlled the operation of the Orion system directly.

The choice of the stars was not made randomly; they are high-temperature stars (their effective temperature is 10,000 and 24,000 degrees -- for Vega and Agena respectively). The investigation of the spectral properties of the high-temperature stars by the means of extraatmospheric astrophysics is of special interest primarily because the basic proportion of their radiation goes for the long-wave range which is inaccessible for observations from the Earth's surface. In addition, the answers to many of the important problems pertaining to the structure of the stellar atmospheres, the sources of the intrastellar energy, the nature of the stellar matter, and so on are directly connected with knowledge of the radiation of such stars in the far ultraviolet range.

The inclusion of Vega in the observation program was dictated by another argument. Vega is one of the brightest stars in the northern sky. In its spectrum there are comparatively few absorption lines distorting the continuous spectrum. As a result of this, it is used by astrophysicists as the standard when studying the spectra of one star or another, the galaxies or the nebulas. This was what was done up to now during observations in the ordinary optical range. The effort to use Vega as the standard even in the far ultraviolet range is natural. In order to do this it is necessary primarily by direct observations to find the energy distribution law in its spectrum in the indicated wavelength range.

The spectrograms of the stars can be obtained using Orion only in the shadow part of the orbit where the station is behind the turn for 30-35 minutes. During this relatively short time the astronaut-observer must find the required star through the port, aim the telescope at it and receive the spectrograms. The entire volume of work with respect to taking spectrographs on the Salyut station was carried out successfully by V. I. Patsayev.

After completion of the observation program, the cassette with the exposed film was removed from the telescope housing and brought into the manned compartment of the station by a special lock. The handling of the cassettes in the lock was the duty of V. N. Volkov.

The exposuee and further processing of the film were carried out after it was delivered to the Earth.

Before putting the Orion on the orbital station, the telescope with the spectrograph was calibrated energywise using the synchronous radiation of a ring electron accelerator. As a result, the relative spectral sensitivity of the equipment required for decoding the spectrograms was known in advance. The spectrograms required to construct the characteristic curve were taken (under ground conditions) in the sections of photographic film which remained unused inside the Orion cassette. For this purpose V. I. Papsayev rewound the remaining film on the receiving cassette at the end of the programmed work onboard the orbital stations. The standard spectrograms were obtained under laboratory conditions immediately after the film was delivered to the ground. As a result, complete uniformity of the physical parameters of the basic and standard films was insured.

The final processing of the spectrograms obtained by the Orion was done in the usual manner. As a result, the energy distributions were found in the spectra of Vega and Agena in the wavelength range of 3,800-2,000 Å.

The observations of Vega and Agena gave extremely interesting results. It turned out that the energy distribution in the spectrum of Vega in the 3,800-2,000 Å range agrees well with the theoretical models. This permits us to hope to use Vega later as a convenient and reliable spectrophotometric standard in the wavelength range shorter than 3,000 Å (to 2,000 Å).

The Agena observationsdata obtained by Orion compare with the results of observations performed by automated observatories. The presence of an energy discontinuity in the continuous spectrum at the boundary of the Palmer continuum (λ = 3,646 Å) is confirmed. In addition, significant divergence between the observed and theoretical distributions is detected. In particular, the observations indicate greater stellar energy by comparison with the theoretical data. The divergence increases with the conversion to the shortwave side and already at a wavelength of 2,000 Å it doubles on the intensity scale. The probable error of these measurements obviously is low. Therefore, the indicated divergence must be considered real. Obviously, it indicates lack of correspondence of the theoretical model of the photosphere to the real condititions of Agena which is a bright giant.

On the Vega spectrograms the far absorption lines of the Palmer series of hydrogen were clearly revealed (beginning with H_8, H_9 and farther). The doublet of ionized magnesium (2,796 and 2,803 Å) merging into a broad line was easily visible also near the 2,800 Å line. The comparatively tense absorption line on a wavelength of 2,500 Å and the other weak lines in the shortwave end of thesspectrogram is quite clearly isolated.

It is necessary to emphasise that the analyzed spectrograms of Vega and Agena were obtained for the first time in the world by an astronomer-astronaut beyond the limits of the Earth's atmosphere. In addition, they are the first shortwave spectrograms of the size obtained under extraatmospheric conditions.

As anaanalysis of the flight data demonstrated, the operating principle of the orbital observatory controlled by an astronaut who is not a professional astronomer was completely justified and can be used hereafter when developing the designs for improved space observatories.

Experiment in Studying Cosmic Gamma Radiation

The most complete representation of the nature and properties of the various space objects can be obtained only by investigating all bands of their electromagnetic radiation, including the shortwave band known as gamma radiation. The gamma radiation occurs during the processes of interaction of high-energy particles with a material and the radiation and annihilation of matter and antimatter. The study of cosmic gamma radiation permits us to obtain information about the density of the gas, the electromagnetic radiation and the cosmic rays at different places in the universe. In a number of cases, for example, when evaluating the fluxes of intergalactic cosmic rays, the gamma astronomy data areedefining.

The study of cosmic gamma radiation is possible only beyond the limits of the Earth's atmosphere. The atmosphere is opaque with respect to gamma quanta, and it is itself a source of secondary gamma radiation created by charged cosmic particles. The cosmic gamma radiation is basically recorded now either by means of highaaltitude balloons lifting telescopes to the limits of the atmosphere or bhboard spacecraft carrying instruments outside the boundaries of the atmosphere.

In fhe future such studies will undoubtedly come to be performed from the surface of the heavenly bodies free of an atmosphere, for example, from the moon. This is convincingly indicated by the experience of the long-term operation of Lunokhod-1 and Lunokhod-2. The stormy development of the techniques and equipment for space flights has promoted numerous studies with respect to gamma astronomy and the first results in space have been obtained.

The studies of the cosmic gamma radiation performed up to now have been of the nature of the first exploratory research. Random scanning of the sky and rough gridding of the recorded fluxes to the celestial coordinates have been characteristic of them. The accuracy of orientation of the satellites on which the instruments were installed was relatively low; in the best case, to a few degrees, and the instruments rigidly installed onboard realized passive scanning of the parts of the sky falling into their field of view. The instruments used in these research experiments were gamma telescopes comprising scintillation and Cherenkov counters recording only the fact of gamma-quanta hitting the instrument and with a very large error in determining the energy of the gamma quantum. The direction of arrival of the gamma quantum was determined with accuracy of no less than the viewing angle of the telescope which was usually 20-30 degrees. The application of narrowly directional and, consequently, low-transmission telescopes would be unjustifiable in research experiments as a result of the shortness of the observation time and the smallness of the expected gamma quantum fluxes.

However, the satellite research experiments performed in the Soviet Union and in the USA have already provided many new results. They demonstrated that there are real grounds for converting to a more detailed study of the gamma radiation of cosmic subjects and, above all, the study of discrete sources of gamma radiation, among which the center of the galaxy, the x-ray stars and the nonstationary extragalactic objects are of greatest interest.

The favorable conditions for performing systematic purposeful studies of cosmic gamma radiation, in particular, the study of discrete sources are created on the orbital station controlled by the crew. The gamma-astronomical observations from onboard the manned station provide more valuable scientific information by comparison with the satellite information.

The homing of the gamma telescope and tracking of defined parts of the sky are realized more simply and reliably. This means a transition from passive scanning with respect to the entire sky to active investigation of individual sections, from random search to the study of defined, most interesting space objects, and it means a qualitatively new step in gamma astronomy.

The instrument serviced by an astronaut can be more informative than the instrument sent on an unmanned satellite. It can operate in various modes: record gamma quanta, protons and electrons which offers the possibility of performing correlation measurements. Here, the operating modes of the instrument will be changed by the astronauts both on instructions from the ground and operatively by decision of the astronaut himself.

The astronaut can control the proper functioning of the telescope in flight, do preventive maintenance work and also eliminate failure to the replacement of individual units.

The gamma telescope onboard the orbital station has better angular resolution. This is achieved as a result of introduction of a tracking detector into it, for example, a spark chamber, in which it is possible to trace the path of each electron-positron couple arising during conversion of the gamma quantum and define the direction of flight of the gamma quantum. The events in the spark chamber will be photographed on film, and the astronaut can trace the expenditure of the film and replace the cassettes. The angular resolution of this telescope is determined by the accuracy of measuring the trace in the tracking detector and is 1-2 orders bettr than for the gamma telescopes used on the satellites. The speed [transmission] and effective area of the telescope not presently connected with the angular resolution can be sufficiently large to record small cosmic fluxes. The optical intake of data from the spark chamber is the simplest and informatively most complete.

The Anna-III telescope was installed on the long-term Salyut orbital station. According to technical specifications, this telescope can record cosmic radiation with an energy of $E\gamma \geq 100$ megaelectron volts.

The instrument comprises a series of scintillation counters and a Cherenkov counter recording the necessary events using an electronic separation circuit, two tracking spark chambers recording each isolated event, a stereophoto recorder with changeable cassettes and servomechanisms and monitoring elements. The gamma quantum incident in the field of view of the telescope passes without interaction through the ventilation counters C_1 and C_2 and in a lead converter with a probability of about 20 percent it creates an electron-positron couple. The electron and positron, being charged particles, cause response of the scintillation counters C_3, C_4 and the directional Cherenkov counter $\mathcal{G}$, which records only the particles moving from top to bottom. The pulses from the C_3, C_4 and $\mathcal{G}$ counters go to the triple comparison circuit and then to the circuit isolating the investigated events. If signals do not arrive at theccircuit at the same time from the counteres C_1 and C_2, a pulse is generated which startes the pulse voltage generators feeding high-voltage pulses of 25 kilovolts and a duration of about 10^{-6} seconds to the spark chambers. As a result, spark rupture takes place with respect to the trajectories of the particles passing through the chambers. The picture of the events in the spark chambers is photographed by a camera in two mutually orthogonal projections. After of the response of the spark chambers the film in the camera is shifted by one frame, and the telescope is ready to record the next event.

The direction of the gamma quantum is determined by the angles of the traces of the electron-positron pair in the first wide-gap spark chamber. The accuracy of reproduction of the direction is about 1 degree which, as was indicated above, is attainable only in such gamma telescopes. In the second spark chamber comprising four intervals separated by lead plates, the components of the couple create an electron shower. With respect to a number of particles in the shower, the energy of the primary gamma quantum is determined. The spark chambers are filled with technical neon to a pressure of 1 kg-force/cm^2, and they can operate without changing the characteristics for several months.

On the photographic film, in addition to photographs of events in spark chambers, additional data are recorded: the time for the gamma quanta to get into the device, the readings of the intensity meters which measure the total background created by the charged particles, and so on. Some of the operating parameters of the telescope such as the rates of counting the gamma quanta, the low-energy and high-energy charged particles are transmitted to the Earth by means of the telemetric system directly during operation of the telescope.

The disconnection of the "forbidden" counters C_1 and C_2 from the separation circuit permits operation in the charged particle recording mode (primarily the proton recording mode). Depending on the intensity of the flux, the spark chambers can be triggered with a different count.

The physical characteristics of the telescope were determined during calibration under laboratory conditions and on acceleration in beams of monoenergetic electrons and protons. The effectiveness of the double anticomparison counters (C_1 and C_2) turn out to be more than 99.99 percent. This indicates that the gamma telescope can operate under the conditions of a large background from charged particles exceeding the gamma quantum flux by 10^4 times. The recording area is about 90 cm^2, and the geometric factor for the isotropic flux is 22 cm^2/steradian. For dimensions of 600 × 400 × 450 mm, the mass of the instrument together with the interchangeable cartridge and the film reserve of 20,000 frames is 45 kg. The power intake is 14 watts.

The Anna-III gamma telescope is a highly complicated instrument, and only testing it directly under the conditions of space flight will permit judgement of the prospectiveness of using this type of apparatus. Therefore, before the creators of the telescope and the astronauts there were three basic goals: it was necessary to do detailed studies of the fitness of the telescope, to discover the possibilities of investigating gamma-quanta with different orientation of the orbital station and to determine the physical conditions of performing the experiment, that is, find the background of mutual and charged particles both coming in from the outside and occurring inside the station.

The telescope operated in the gamma quantum and charged particle record mode during orbital orientation of the station with stabilization of the station on the Sun and under the twisting conditions with orientation of the Sun for a total of 20 hours. The telescope control and monitoring of its operation were left directly to the astronauts. The initial processing of the data received from the gamma telescope permitted evaluation of the background fluxes.

The experimental results indicate the proper selection of the method of investigating cosmic gamma radiation. The experience obtained will undoubtedly promote further progress in gamma astronomy.

Studies of Charged Particle Fluxes

The problem of the composition and spatial distribution of the particles at altitudes of 200-300 km above the Earth below the boundary of the radiation belts has not been solved up to now. It is unknown what proportion of the particles in the radiation background is protons, electrons or positrons and how they move and how their intensity changes with time. There is still no clear representation of the nature of the increased radiation background near the Earth.

With respect to the problem of the origin of the charged particles there are several points of view: the albedo origin, the diffusion from the belts, and acceleration near the Earth. It is possible that at the indicated altitudes, all of these mechanisms play a role, but it has not been discovered what contribution each of them makes. Therefore, it is of special importance to study the charged particlesfluxes at the orbital station which can be equipped with a large quantity of scientific apparatus, and it is capable of operating for a prolonged period under the control of the astronauts.

In order to record the charged particles against a radiation background on the Salyut orbital station, the Cherenkov-scintillation telescope was installed. The purpose of the experiment was to study the background intensity of the charged particles at altitudes of 200-300 km, the latitudinal dependence of this background and its time characteristics. The increased radiation background at these altitudes was noted from the time of the beginning of studies on artificial Earth satellites in 1960. It turned out that the intensity of the charged particles with an energy of several megaelectron volts and higher exceeds the intensity of the cosmic radiation in the equatorial region by several times. The instrument designed to record the radiation background on the Salyut station had various outputs from the Cherenkov-scintillation sensors and could be converted into various operating modes. The channels were calibrated regularly. During the flight time of the Salyut station, the crew performed more than 60 different operations with respect to recording the charged particles.

The analysis of the results obtained in the region adjacent to the geomagnetic equator shows that here the value of the charged particle flux is 530 ± 90 particles$\cdot m^{-2} \cdot sec^{-1} \cdot$steradians^{-1}. The instrument could record protons with an energy of 400 megaelectron volts and electrons with an energy of 8 megaelectron volts and higher. For protons the minimum energy is determined by the threshold of the Cherenkov counter; for electrons, by the penetrable thickness of the material.

During the process of experimentationoon the Salyut station, it was necessary more precisely to define the problem of the existence of groups of electrons appearing as a result of their acceleration andaltitudes of 200-300 km. The hypothesis was stated earlier of the presence of electron clusters with an energy of 300-600 megaelectron volts. In order to check this hypothesis, the apparatus of the Salyut orbital station permitted a time analysis of the recorded particles. Studies were made of the particles "delayed" with respect to time within thelimits of the 20 microsecond interval. The ratio of the flux of these particles recorded with respect to the number of delays to the total electron flux with an energy of 8 megaelectron volts did not exceed $5 \cdot 10^{-3}$. The data received from the Kosmos-225 satellite demonstrated that the ratio of the flow of clusters of corresponding density to the flow of electrons with an energy of 40 megaelectron volts is $9 \cdot 10^{-2}$. Considering the difference in energy bands of the electrons, it ispossible to consider the established divergence not very large. The small number of "delayed" events with respect to the total number of recorded particles indicates that the problem of the existence of the charged particle clusters required for the research.

Study of the Multicharge Component of Primary Cosmic Radiation

The study of thecoomposition of the primary cosmic radiation is one of the fundamental problems connected with the theory of the origin of cosmic radiation. The experimental data on the composition of the cosmic radiation permit us to draw conclusions regarding the sources of cosmic radiation and the mechanisms of generation and propagation of cosmic rays in intersellar space. The study of the multicharge component of the cosmic rays is especially important also in order to insure radiation safety of space flights.

The cosmic radiation includes heavy multicharge particles in addition to protons and alphaparticles. These multicharged particles are the nuclei of atoms of various elements free of electron shell and moving with different speeds to speeds close to the speed of light. In spite of the fact that in quantitative respects the multicharge component is a total of about 1 percent of the total number of all corpuscular cosmic particles, with respect to mass it is about 1 percent, and with respect to energy release taking place in the matter, about 40 percent. The study of the composition of the primary cosmic radiation presupposes the solution of the following problems.

1. A detailed study of the charge composition of cosmic radiation outside the Earth's atmosphere (on satellites) and outside the Earth's magnetosphere (on automated interplanetary stations). Specifically, this pertains to the range of very heavy nuclei with a charge of $Z \gg 26$. The studies in the indicated range can offer new important information about the sources of cosmic radiation. Let us note that at the time of starting the experiments on the satellites, the data on the heavy nucleus content in the primary cosmic radiation were highly contradictory.

2. The search for transuranium and uranium nuclei in primary cosmic radiation. The detection of such nuclei would have great significance in solving the fundamental astrophysicalpproblems and, in particular, it would permit discovery of the distribution of the sources of cosmic radiation in space.

3. The searches for antinuclei in the composition of the primary cosmic radiation inasmuch as the problem of symmetry of the world with respect to matter and antimatter content is one of the most interesting problems of astrophysics.

4. The search for the Dirac monopole (a single magnetic charge) predicted by Dirac and not detected up to now.

5. Study of the chargedcomposition of cosmic radiation in the field of low and high energies along with the investigation of the energy spectra in the low energy range for particles of different charges. These data are highly significant for understanding the processes of the propagation of cosmic rays and the mechanisms of cutting off the energy spectra in the low energy range.

The advantages of satellites and automated interplanetary stations for the performance of the abovelisted studies are quite obvious. Three of the above-mentioned problems are connected with observing the extremely rare events, the probability of the recording of which depends both on the area of the detector and on the duration of the experiment.

In the experiments with respect to studying the multicharge component, a photoemulsion camera was used as the detector. Such experiments have already been performed previously on the Soyuz-5 spacecraft and the Kosmos-213 satellite and also on the Zond-5, Zond-7 and Zond-8 automated stations. The experiment on the long-term orbital stations Salyut differs significantly from all the previously stated experiments with respect to its duration, and it makes a noticeable contribution to the general statistical material.

In order to investigate the multicharge component of the primary cosmic radiation, a FEK-7 photoemulsion camera with a volume of 1.4 liters combined with plate detectors was installed on the Salyut orbital station. The amount of absorbing layer over the camera was 1.2 grams/cm^2. The photoemulsion recorded the charged particles hitting the chamber, and after completion of the experiment under laboratory conditions on the Earth it permitted a detailed investigation of each individual interesting event. The total exposure time of the camera in orbit was 1,728 hours. The camera was installed onboard the orbital module of the Salyut station before the launch on 19 April 1971. It was removed from the operating position by the astronauts and delivered to the Earth.

The photoemulsion camera was assembled from individual layers of low-sensitivity type A-2 emulsion with a thickness of each layer of 200 microns. The thickness of the layers was selected with a specially chosen development regime permitting certain isolation of the primary heavy nuclei with large charges in spite of the relatively large radiation background in the camera.

The possibility of investigating the primary nuclei over a long run in the emulsion permits reliable separation of the particles strongly ionized as a result of low speed on the particles, the ionization of which iscaused by a large charge.

The experiment on the long-term orbital station Salyut demonstrated the possibility of using the nuclear photoemulsion as a detector under the conditions of prolonged exposures (2-3 months) on space objects.

The data obtained indicate that the procedure for the application of plastic detectors is prospective for studying the multicharge component of cosmic radiation on subsequent space flights.

It is also necessary to note that the use of plastic detectors as threshold detectors can be of significant assistance in the dosimetric control of the astronauts.

The statistical processing of the results of studying the multicharged component and inspection of the irradiated emulsion permitted evaluation of the relative content of the heavy nuclei in cosmic radiation.

It was established that the relative contents of heavy nuclei with $z \geq 33$, $z \geq 40$, and so on outside the Earth's magnetosphere have approximately the same magnitude as outside the atmosphere, but within the limits of the magnetic field.

As for the most discussed and interesting person of the existence of uranium and transuranium element nuclei in the composition of the primary cosmic rays, its solution requires further experimentation on the Salyut manned orbital stations.

Study of Meteoritic Material

The studies of the meteoritic material in outer space have both scientific and practical significance permitting evaluation of the meteoritic danger with which it is necessary to deal during prolonged flights of the heavy spacecraft and orbital stations. The statement of these studies on the orbital stations can give the most significant results inasmuch as the necessary duration of the experiment and the possibility of placement of a sufficient number of sensors on the hull of the station with a large area of sensitive surfaces for recording meteoritic particles is insured.

On the Salyut orbital station an experiment was performed to determine the spatial density of the meteoritic material. The meteoritic particles were recorded by means of capacitor and combination capacitor and piezoelectric sensors.

In the case of breakdown of the sensor by a meteoritic particle, short-term shortcircuiting of the plates by the ion shell takes place. This arises as a result of the interaction of the high-speed particles with the barrier. Therefore, the fact of this short circuiting of the capacitor in flight indicates rupture of it by a meteoritic particle.

Study of Meteoritic Materials

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On the Salyut orbital station an experiment was stated with respect to determining the spatial density of the meteoritic material. The meteoritic particles were recorded by means of capacitor and combination capacitor and piezoelectric sensors.

In the case of puncture of the sensor by a meteoritic particle there is a brief short circuit of the jacket of the ion shell occurring as a result of interaction of the high-speed particles with the barrier. Therefore, the fact this short circuit of the capacitor in flight indicates puncture of it by a meteoritic particle.

One group of sensors was placed in the rear section of the orbital module near the solar cell panels; the other was placed on the outer surface of the hull in the large-cylinder zone. The information from the two sensors of identical sensitivity was summed by the electronic module of the orbital station. The thickness of the sensitive surfaces of the sensors was taken as 30 and 40 microns, and the area of the sensitive surfaces was 0.33, 0.34, 0.5 and 0.85 m^2.

The capacitor sensors placed near the solar cell panels recorded a higher meteoritic particle flux than the sensors of the same sensitivity placed on the surface of the large cylinder of the hull several times. Obviously, this can be explained by recording of the first group of products of destruction of the solar cells ejected during impacts of the meteoritic particles on their surface by the first group of sensors.

When processing the experimental data about recording the meteoritic particles by the sensors during the period from 15 June to 27 June 1971 for a total time of $8 \cdot 10^5$ sec, the total number of punctures, the mass of the meteoritic particles and the spatial density of the particles were discovered. It is characteristic that the piezosensor adjusted to record meteoritic particles with large masses of $m \geq 4 \cdot 10^{-6}$ grams had no response.

The experimental results on the Salyut station significantly supplemented the available information about the spatial density of meteoritic material in the space about the Earth (in the region of low-mass meteoritic particles), and they permit the designers to consider the meteoritic danger during the design calculations. In addition, new data were obtained to improve the apparatus recording the meteoritic particles.

Complex Photographic Experiment for Solving Scientific and National Economic Problems

One of the basic divisions of the scientific research program on the Salyut orbital station was the complex photographic experiment. Photographing the Earth from space provides valuable scientific information. It was done previously, but on a smaller scale. Onboard the orbital station Salyut there was a large complex of stationary and manual photographing equipment of several types which determined the scales of the photographic experiment.

The success of the experiment was promoted by a great deal of preparatory work during the course of which a careful analysis was made of the demands of various branches of the national economy. A method of selecting the optimal parameters of the photography system was developed which is based on analyzing the problems of taking the photographs, the characteristics of the photographed object, the conditions of making the photographs, the modern possibilities of optics, the photographic equipment and photographic materials.

The active participation of the station crew and performance of the experiment permitted a significant increase in its efficiency by making a purposeful selection of the most interesting objects in scientific respects. In addition, the presence of the crew simplified the solution of the problems of preparing the onboard equipment, and it permitted its adjustment in flight.

As a result of the experiment, planned, highly informative photography of several parts of the Soviet Union was carried out on different scales.

Problems, Apparatus and Organization of the Experiments

The statement of the photographic experiment was preceded by more precise definition of the list of scientific and national economic problems, the solution of which by the methods of space photography is the most expedient; the development of the apparatus and methods of taking photographs and photographic and photogrammetric processing of space photographs, the development of the methods of scientific interpretation and practical utilization of space photographs.

When preparing the experiment about 100 problems from the fields of geography, geodesy, geology, farming, lumbering and fishing, land improvement, hydrology, meteorology, oceonography, and so on were formulated and analyzed. These problems included, for example, the creation and renewal of the various maps (topographic, geologic, geobotanical, soil, and so on); the discovery of the geological structures prospective for finding minerals, the study of the distribution of the snow and ice cover, the study of the conditions of thawing of the snow and flooding of the rivers, observation of the movement of sea ice and the detection of icebergs, evaluation of the moisture reserves in the soil, estimation of the water and wind erosion, observation of the water pollution in the rivers, lakes and seas, detection of ground water sources, taking inventory of the forests, taking inventory of farm lands, evaluation of the state of crops, study of the shore destruction and the formation of sand bars, study of the relief of the ocean floor in the coastal zones, and the study of marine currents, and so on.

By using photographic equipment, certain other problems were also solved: the recording of visual observations of the cosmonauts, the recording of the results of technical experiments, photographing the stars in order to grid the Earth photographs, construction of the geodetic grid and determination of the dynamic characteristics of the station.

The laws of distribution of the relative number of problems solved by photographs were defined as a function of the required magnitude of the resolution on the terrain and the coverage of the terrain.

The structural designs of the fixed cameras provided the possibility of solving the basic scale of the photographic experiment. However, the variety of problems of the complex experiment and photographic subjects required the presence onboard the station of two more manual cameras with interchangeable optical systems, broad possibilities for varying exposures and light filters, and so on.

<u>Selection of the Parameters of the Basic Photographic Equipment and Movie Cameras</u>

The problem with respect to selecting the optimal parameters of the photographic system for taking pictures of the Earth was solved in two steps. First, the system was considered which with minimum focal length of the objective insured given resolution locally. Then the actual objective with the focal length close to the calculated focal length was selected. The resolution of the objective as a function of the different factors was more precisely defined experimentally. The values of the resolution locally were calculated for all possible combinations of the remaining parameters (delay, stop setting, light filter, film, developer, development conditions). The combination of these parameters was selected for which the best resolution was obtained.

The exposure calculation and the selection of the parameters of the camera were made for the average conditions of photography for which the spectral albedo of the brightest and darkest of two objects were assumed constant with respect to spectrum and equal to 0.1 and 0.05 respectively (the steppes, dry meadows and fields, and so on have an albedo close to 0.1, and rivers, lakes, very wet sections, coniferous forests, freshly plowed fields, and so on have an albedo close to 0.05).

The zenith distance of the sun was assumed equal to 75 degrees so that under any conditions the image obtained using the selected apparatus does not fall into the region of underexposures. The spectral optical thicknesses and the scattering indexes cassedponded to the average state of transparency of the atmosphere.

The photographic material was selected by the results of studying the

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image properties of the entire photographic system considering the atmospheric-optical requirements and the possibility of obtaining the maximum information about the photographic objects. The evaluation of the informativeness of the photographs was made on the basis of an analysis of individual indexes entering into the formula for the information capacity of the photographic system.

When wselecting the apparatus for photographing the stars we began with the necessity for obtaining images of no less than three stars on the photograph (for the expected rates of rotation of the station around the center of mass). In addition, the problem of combining the functions of photographing the Earth and the stars in one camera was stated. This problem could be solved by adjusting the apparatus which was done by the cosmonauts during the photographing process. After preliminary analysis and the necessary calculations, the onboard set of photographic and movie equipment was finally defined.

Before the flight, the photometric and photogrammetric calibration of the stationary cameras was carried out, and the exact position of their coordinate axes with respect to the axes of the orbital station was determined.

After photographing the Earth by one or two cameras, the cosmonauts were able to photograph the stars with one of the cameras, make a synchronous photograph of the stars with both cameras, and take a synchronous photograph of the Earth and stars.

In all of the enumerated cases the cosmonauts have taken photographs either with any interval (more than one second) between the frames or they have given the automatic photographing mode with a defined interval between pictures within the limits from 1 to 60 sec. The cosmonauts controlled the operation of the cameras during the time of taking the photograph by using special indicators installed on the control panel and on the apparatus itself.

The manual cameras were used both for external photographs through the ports and for internal photographs (in the station compartments). In order to determine the exposure conditions of these photographs the cosmonauts had onboard exposure meters available. The required level of illumination during the photographs inside the station was achieved by using a portable light.

Organization of and Taking Photographs

Photographs taken from the Salyut orbital station can be divided into two groups: photographs of the objects with respect to indications of the ground control group; photographs of objects by examination of the crew in the process of visual observation.

The photographs of the first group required preparatory work with respect to organization of the experiment and also insurance of operative control of the course of the experiment (including the operation of the station crew and direction of the experiment by the ground service group). The preparatory operations were performed in the absence of specialists of the different branches of the national economy.

In order to obtain the maximum volume of information, several regions were selected in the territory of the Soviet Union, the photographing of which from space was of the greatest interest from the point of view of studying the natural environment. The aerial photographs of these regions were taken first on different scales and certain other operations were performed. For each region the initial data were defined by photography: the required resolution locally, the optimal sun altitude, the overlap of the photographs, the orientation regimes, and so on.

On the basis of the results of the preparatory work, a program was compiled for taking the photographs determining the sequence and conditions of operations of the complex photographic experiment. Durigg the process of the flight, the operative ground group prepared the initial data for implementing the program and monitoring its execution.

In order to take good quality photographs, the information about the meteorological situation was taken into account. The service group successively obtained the seven day, three day and 24 hour weather forecasts in the previously coordinated regions which offered the possibility of more precise definition of the operating orbits for the photographic experiment.

The main ballistic group published the necessary data with respect to the actual orbit of the station: the height of the orbit, the geographic longitude, the time of intersection of the equator by the operating orbit, the time of passage of the station over the photographing region, and so on.

Analyzing all of the data obtained, the service group transmitted the radiogram to the station containing the necessary data for the photography session. The station crew prepared the camera to take photographs (loaded the cassettes with the selected film, set the stops, the speed, the light filters, and the photographing interval) and in accordance with the program took photographs of the sections of the terrain. On completion of the photographing session data were transmitted to the Earth on the course of performing the experiment.

After completion of the space photography program, the removed film was delivered to the ground for photochemical processing, a detailed analysis of all the materials obtained and multiplan decoding.

Photographic Processing and Characteristics of the Materials Obtained

Photographs of the Earth from the Salyut orbital station were taken in a wide range of illumination (sun altitudes varied from 10° to 60°). Objects very different with respect to their brightness characteristics were photographed: from dark (water surfaces) to very bright (clouds, snow), from low contrast (deserts, continuous clouds) to high contrast (mountains with snow, individual clouds above the water). So that in any of these cases high quality negatives would be obtained, it was necessary to provide for the possibility in the photo processing of varying the sensitivity and the contrast of the photographic material within broad limits (for the sensitivity it was necessary to insure approximately tenfold variation of it; the contrast had to vary within the limits from 1.0 to 3.0).

In addition, in practice none of the Soviet or foreign developers with known formula provided for the listed requirements. Accordingly, a formula was developed for special developing solutions, and the conditions of processing the film were established which permitted regulation of the contrast within a broad range (from 0.65 to 3.0) simultaneously with improving its sensitivity.

Before proceeding to chemical-photographic processing of the exposed film, the necessary preparatory work was done: according to the notes in the onboard log, the synoptic maps, the television pictures received from the meteorological satellites and other materials, a careful study was made of the conditions of taking the photographs (the actual state of the weather, the transparency of the atmosphere, the characteristics of the photographed landscape, the illumination conditions) were carefully studied, and the exposures obtained by the film in each specific case were calculated. On the basis of this, sensitometric indexes of the photographic material were calculated. These indexes were necessary to insure high photographic quality of each of the negatives, and the formulas for the developers and the development conditions were selected.

The photographic film on which the stars were recorded was developed in the standard developer to maximum values of the contrast and sensitivity in order to obtain the largest possible number of images of the stars.

When taking photographs by a manual camera, the exposures were determined by the cosmonauts directly before taking the photograph using the exposure unit which provided the optimal film exposure. Therefore, the manual photographic material was also processed in standard developers.

Meteoritic Analysis of Space Photographs of the Cloud Cover

In order to solve scientific problems and insure the operative work of the weather service, meteorology is in need of global information about the atmospheric phenomena on the scale of the entire planet. Along with this, individual periodic observations of the meteorological phenomena from space for the performance of research work, the development of methods of using information and improving the methods of the observations themselves were highly valuable. This type of material was partially obtained from the Soyuz manned spacecraft. As for the operative weather service, it requires continuously incoming meteorological information.

The beginning of working with respect to a systematic investigation of atmospheric phenomena from a manned orbital station was set down by the crew of the first orbital station, Salyut. Onboard the station observations were made of the atmospheric phenomena, the cloud cover and the surface of the oceans and seas not covered by clouds. They included primarily the visual survey of the Earth and the space about the Earth. In addition, photographs were taken of remarkable or unusual phenomena.

The part of the planets occupied by the oceans where the meteorological station network is extremely sparce and the information about the phenomena in the atmosphere above the ocean and its interaction with the ocean is highly limited aroused special interest.

The observations from the Salyut orbital station encompassed a broad class of meteorological phenomena. Studies were made of tropical cyclones which occur in the equatorial part of the oceans and bring mankind enormous misfortune. Cloud systems are connected with the cyclones which appear from outer space in the form of compact cloud vortexes.

A no less important problem consisted in observing the surface of the oceans and the clouds themselves formed above the oceans. The observations of the ocean surface permit distinction of the nonuniformity in color of the water connected with the ocean currents, the deep-water outlet, discharge into the oceans from large rivers. The observations of the cloud cover above the water reveals the variety of cloud outlines, the shape of which is connected to the defined structure of the movement of the air above the ocean surface.

Meteorological observations from onboard the orbital station were performed by the previously developed procedure considering the observation experience during preceding flights on the Voskhod and Soyuz manned spacecraft. The cosmonauts conducted independent work with respect to the program, and they obtained the required consultation about the regions of observation of the interesting cloud formations and other atmospheric phenomena in the extratropical and tropical latitudes of the Southern and Northern Hemispheres.

The station crew visually recorded and photographed many interesting cloud situations unavailable to aircraft observations and not distinguishable on the photographs in automated satellites. The route photography permitted an image to be obtained of the mesoscale cloud subjects. Their conditions of occurrence and their dynamics are a special division of meteorology, ~~mesmeso~~ meteorology.

An analysis of the photographs of the cloud cover and the underlying surfaces from space permits discovery of a number of mesometeorological peculiarities.

Above all, attention is drawn to the fact that the large valleys and ravines on the photographs (page 108) are free of clouds. This can be explained by the effect of the night wind causing settling of the air above the valley. The cloudless valleys permit easy orientation on the orography[1] of the region. The morning convection occurs on the mountain slopes along the side of the valley illuminated by the sun. The clouds formed do not accumulate on the ridge itself, but they remain for a long time on one or both sides of it. If the ridge is covered with snow, the cumulus clouds are not formed above this cold underlying surface.

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[1] Orography is the characteristic of the forms and dimensions of the surface relief, its height and extent.

The stratocumulus clouds above the mountains the origin of which is connected with the preceding cyclonic activity, are isolated on the photographs. In the mountains, the snow line is clearly outlined with all of its details. The texture of the ridges covered with snow is distinguished sharply on the photographs from the texture of the cloud cover.

The results of analyzing the photographs of broad occluded[1] cyclones is of great interest. The cloud system of this cyclone usually is a gigantic vortex to 2000 kilometers across. With respect to tone and structure, the cloud images are well-distinguishable from the characteristic features of the air circulation in the central part of the cyclone. Obviously, the vortex structure in the center of the vortex is made around which the spiral cloud belts converge.

The cloud system of the low cyclone recorded by the Salyut crew from the series of those which frequently shift under the effect of the subtropical jet stream turned out to be no less interesting. The cyclone was detected over the western part of the Pacific ocean at a latitude of about 35° north of the equator. This was a cloud vortex predominantly made up of cumulus clouds. Somewhere the cumulus clouds were covered with a film of cirrus clouds which are the merging tops of the cumulonimbus clouds. Attention was given to the differences in the front and rear sections of the low-cyclone cloud spiral. Under the conditions of a positive water-air temperature difference (1-3 degrees) which was observed in the front section of the cyclone, stratocumulus clouds arose in the form of polygonal cells. In the rear of the cyclone a small cumulus cloud was observed. In the photographs the unquiet nature of the clouds are clearly exhibited indicating the stormy development of the convective processes in the cyclone. This is a distinguishing feature of the low-latitude cyclone.

The dimensions of the parts of the mesoscale cloud formations are such that they cannot always be recorded by the camera of meteorological satellites on the strength of the small resolution. At the same time, the extent of the mesoscale systems is tens and hundreds of kilometers on the basis of which they cannot be encompassed by an aerial photograph. These cloud formations reflect the dynamics of the lower part of the atmosphere in interaction with the underlying surface. From manned spacecraft, as the experience in taking photographs from the Salyut station shows, the mesoscale phenomena are detected especially clearly. For the planned photography in a series with overlap of adjacent photographs insuring stereoscopic processing of them, it is possible to obtain the spatial structure of the mesoscale cloud formations.

The meteorological analysis of the photographs of the cloud formations is only one of hte many meteorological problems on the level of investigating the atmosphere from space. Later, the means of observation from onboard the orbital stations will, of course, be expanded and improved. The practical value of performing such operations is difficult to overestimate. There is not one branch of the national economy or science which to one degree or another

[1] Occlusion is merging of the cold and warm fronts of air in the vicinity of a cyclone.

would not need knowledge of the exact laws of the development of the processes occurring in the atmosphere and hydrosphere of the Earth.

Geographic Interpretation of the Space Photographs and Analysis of the Natural Environment

In scientific and popular scientific foreign and Soviet publications scientific and practical effectiveness of photographing the Earth's surface from spacecraft has been noted more than once. In particular, defined results were obtained on the basis of executing the program of photographing the geo-geological-geographic subjects of the Earth's surface from the Soyuz manned spacecraft. The results of taking photographs from the Salyut manned orbital station were a further development of this program. They permitted comprehensive analysis of the space photographs of different scale. The smallest scale photographs (1:500,000) were used to accumulate scientific-procedural experience in the survey thematic geologic-geographic mapping. The photographs on a 1:2 million to 1:3 million scale are necessary to obtain the scientific-procedural experience of the mean scale mapping and studies of the natural environment.

Some of the researchers propose that the smaller scale photographs were not effective for geological-geographic purposes. However, an attentive analysis of the photographs made during the flight of the Salyut orbital station on a 1:7 million to 1:8 million scale refute this opinion. First, such photographs can be used to fix the short-term in seasonal phenomena which require simultaneous capture of broad territories. For example, such is one state or another of the snow cover, the river floods, the occurrence and propagation of dust storms, the state of the vegetation of the plant cover, and so on. Secondly, these photographs offer the possibility of checking and more precisely defining the boundaries of a number of broad and permanent natural phenomena developed in large territories, for example, the boundaries of the physical-geographic zones and large natural regions, the principal types of soil-plant cover, the morphological structures and, and in terms of them, the geographic structures, the large tectonic linaments, and so on.

An analysis of the small-scale photographs of plains and hummocky deserts permits isolation of the types of terrain on the dry land the bodies of water by the differences in tone of the image, configuration of the tonal separations, their structures caused by the physionomic features of the landscape. The lakes and lacustrine plains are recognized by the soft iridescence of tone of the water surface from light, but spotty, to dark and the sharp image of the shores. If on the photographs the sharp variations in tone of the image of the body of water are almost not visible, this indicates the great turbidity of the lake water at the time of taking the photographs. In the river mouths, sharp outlines of the underwater sandbars are outlined in cases of great transparency of the lake water and low turbidity of the river water.

The alluvial and delta plains and valleys of the permanent rivers differ sharply on the photographs both with respect to tonality and with respect to the figure. The modern valleys of permanent rivers are expressed by the darkest tones with a sharp outline and sinuous figure caused by meandering of the rivers. The total darkness of the outline is wholly connected with the seasonal flooding of the flood plains and the increased moisture and density of the plant cover retained during the remaining seasons.

The low degree of modern deltas of permanent rivers is recognized by the deeper tone and presence of striated-sinuous-spotty patterns caused by the effective currents in the lakes. The creation of sharply contrasting bodies of water with unflooded sections creates broad variation of background and it is a clear indicator for decoding.

The upper stage of the modern deltas of permanent rivers with a general lighter tone retains the same broken-striated pattern. The lightness of the tone is connected with significantly lower water content of the territory flooded only at especially high floods, the sparseness of the vegetation and the high degree of development of shallow sandy (extrascale) sections. The dark background of the channels and streams indicate that they are flooded.

The flowing parts of the deltas are read on the space photographs by a characteristic combination of the striated figure of two gray tonalities with white streams, spots and points. The darker gray tone, judging by the clarity of the figure, corresponds to the maintained network of dry dead rivers; the light tone with more indistinct outlines and boundaries indicates the less maintained interfluvial relief of the delta and "silting" of it by the processes of interlayering of the sand, and the light elements of the figure are the clayey areas of the takyrs which have no vegetation.

The area of low, rounded isolated hills and its proluvial inclined plain are recognized on the fine-scale pictures by the white branched erosion network of dry valleys of the overdrying temporary streams combined with the spotty tone of the watersheds.

The white color of the dry valleys of the overdrying and temporary rivers and streams is caused by the gravel stripped of vegetation, the gypsum desert crust and the solonchaks [saline soils]. The deserty of this network which is comparative small in the presence of spotty tone of the interfluvial spaces indicates the widespread nature of the denuded outcroppings of bedrock.

The proluvial plain with the outcropping of rock shows up in the pictures as spotty sections of outcrops of bedrock which are combined with segments of more sustained tonality of the proluvial and deluvial plains.

The hummocky area, the hill country and low-mountain region are revealed with respect to the dense erosion network, with respect to the large area of the spotty texture of the image of outcrops of rock and by their tone. An increase in the tonal density of the positive image indicates the transition from the desert subzone with plant life to the semidesert with denser plant life and to the dry steppe subzone with greater density of the unburned grass cover. The low mountain region differs from the hummocky area and the hill country with respect to an increase in the outcrop areas.

These are examples of recognition of geographic objects which can be directly read off the small-scale (survey) photographs, and they do not require additional ground studies for their recognition.

The soil-botanical interpretation of the small-scale space photographs also permits more precise definition of the characteristic features of the natural environment. The differences in tonality and other decoding attributes, and with the data from the ground study of the terrain helps sufficiently completely to isolate the landscape components and the soil-plant divisions. Rocky deserts covered with sparse semi-bushy plants comprising a mosaic combination of sage brush associations characteristic of the typical brown soils and different types of other plant associations in the browndsolonetz [structural alkali soil], the brownd detrital weakly developed soils and brown solonchak [saline] soils.are distinguished.

The plant cover has no significant effect on the tone of thessurface image. The rocky plains are depicted on the photographs in dark grey tones corresponding to the outcrops of dark volcanic and sedimentary rock.

The comparatively sparse plant cover of the sand also has no significant effect on the image tone. In the regions of again winnowed plains covered with sandy massifs, an even grey tone prevails which is lighter in the places with an abundance of incoherent sand.

In the pictures in the valley regions of permanent rivers, dense woody-bushy and grassy plant life prevails. It is possible to distinguish the willow-elaeagnus tugai, motley grass and reedgrass associations in the meadow-solonchak soils, irrigated fields and laylands. The valleys are clearly distinguished by the narrow weakly winding strips of uniform dark-grey color with sharp boundaries. The tone of the image depends primarily on the presence within the valleys of more or less dense moisture-loving vegetation.

The analysis perfommed indicates that both for "open" territories, that is, for hummocky and hilly deserts and for "closed" quaternary deposits of the desert plains, the small scale of base photographs bears very large and varied information. A still greater volume of information can be obtained when interpreting the space photographs using the available ground information.

The method of geomorphologic interpretation with respect to small scale space photographs permits in certain cases new data to be obtained on the peculiarities of the structure and propagation of the relief. Thus, for example, on one of the space photographs part of the lacustrine region is recorded the landscape of which is characterized by a combination of medium and high hills, forested and unforested, sometimes with spots of snow on the peaks and the intermontain depressions separating them within the limits of which the steppes, semideserts and deserts have developed.In many of the intermontain depressions, lakes are encountered, and in some of them there are sandy massifs with deflated sand.

The bottoms of the depressions are usually a gently undulatedg plain made up of alluvial-provluvial deposits. The depressions are clearly differentiated with respect to the comparatively uniform gray tone of the image caused primarily by the nature of thesoil weakly masked by the vegetation of the desert wormwood-stipa steppes. The uniformity of thelandscape is destroyed by several lakes separated by very dark spots. The river valleys are depicted by narrow weakly twisting strips of dark gray tone and a large sandy massif. On thewwhole the sand is weakly fastened by the plant cover, and it is depicted on the photography by a light grey andgray tone sharply contrasting with the image of the surrounding silt and detrital plain.

An analysis of the space photograph permitted the discovery of an entire series of peculiarities of the morphology of the sandy massif, its macrostructure and mesostructure. The striated nature of the structure of the entire massif as a whole caused by ridged nature of the sand can be seen while on the photograph. The rows are oriented in the same direction as the massif as a whole. This orientation of the dunes and the massif is determined by the direction of the prevailing winds.

By the photograph it was possible to determine the propagation of the barkhans, the relief and the sizes of the barkhan chains. The region of propagation of the barkhan sand almost entirely free of plant life is depicted on the photographs by the lightest background.

On the photograph more than 10 narrow transverse, extended barkhan chains can be seen which are perpendicular to the direction of the large longitudinal sandy ridges. This sand is significantly more fastened than the vegetation which causes a relatively darker tone of the image. The strips of sand rising to the rocky surfaces of the mountain slopes are traced in the form of narrow tongues.

Thus, as a result of analyzing the space photographs new data were obtained on the peculiarities of the structure and propagation of the eolian relief of the poorly studied sandy massif.

The small-scale space photographs can be successfully used for the new publication of the Soviet physical-geographic atlas of the world. Its compilation and publication were an important event in world geographic science.

At this time the atlas needs revision. First, during the period taking place since the completion of work on the Aalas, that is, in the last 10 to 15 years, known variation of the natural environment has occurred. Secondly, new geographic data have been obtained and the previously known information has been more precisely determined (in particular by the space photographs) on the natural conditions in the territories which are difficult of access and poorly studied. Thirdly, use of the space photographs significantly improves the cartographic accuracy of the boundaries of many of the natural formations and also the degree of their detail. Finally, the application of the space photographs improves the technology for compiling the small scale topical maps which make up part of the world atlas for which, for example, the multistep cartographic generalisation is replaced by direct recognition of contours by photography.

A comparison of the decoded space photographs with the corresponding sections of the geomorphological maps from the physical-geographic atlast of the world demonstrated that the maps compiled by the space photographs can be distinguished by more precise outlines of the contours and significantly greater detail.

By the medium-scale space photograph (about 1:3,000,000), highly detailed characteristics of the structure of the relief, the soil and plant cover, the surface water and natural landscape can be obtained.

Detailed photographs from the Salyut orbital station provide for stereoscopic recording of the forms of the relief with dismemberment of no less than several tens of meters, that is, the micro and mesoforms of the relief. The forms of the relief not perceived as stereoscopically are reflected well on the photographs as a result of iddirect signs, for example, the distribution of the vegetation.

The erosion dismemberment of the territory finds very good reflection in the photographs. The picture of the erosion network in the regions of the black taiga appears quite clearly. The unforested bottoms of the valleys and troughs are distinguished against the dark background of the forest. In the foothills meadow-steppe and forested steppe regions the erosion forms are distinguished by the darker tone of the high-grass meadows or the birch groves by comparison with the lighter tone of the plant groupings on the watersheds. The representation of the entire system of erosion forms makes the pictures valuable material for discovery of the density of dismemberment of the territory which was determined up to now by the topographic maps where part of the forms unavoidably are lost as a result of generalization.

The clear depiction of the forms of gullied erosion on the photographs has great practical significance. The contours of the ravines are outlined by the configuration of the fields surrounding them and sometimes by the spica forests on their slopes. The brows of the slopes are well expressed. The separation of the old erosion forms of the ravines from the new ravines is possible. The new erosion cuts along the bottoms of the ravines, and the apexes and mouths of these forms are clearly recorded.

The structure of the river valleys is well reflected in the photographs, in particular, the floodplains of the rivers. The terraces of the lowland rivers are distinguished by indirect signs. The high terraces of the large mountain rivers are visible. The microforms of relief of the plains and forested plateaus find especially good reflection -- the l ustrine depressions, the dead lake depressions, the sagged suffosion relief. The dismembered sections of the low hummocky areas near the rivers are clearly distinguished.

The forms of aeolian relief of sands in the trough of the ancient discharge indicating the broad development and large variety of dune forms are well visible. This reflief is difficult to study in the field as a result of the fact that the territory is covered with pine forest.

In addition to studying the types of relief of different genesis, the medium scale space photographs turn out to be useful also for the execution of such tasks as the correct drawing of the boundaries of the foothill, low mountain, medium and high mountain regions inasmuch as in addition to the topographic maps they provide a complete map of the nature of the dismemberment of the territory.

The soil cover of the photographed territory is well-reflected on the medium-scale photographs. The plowed fields are isolated through differentiation in tone of the soil surface; and in the condition of the planted fields. In the sections which are unsuitable for plowing, the indicaoor is the relief and natural vegetation.

The good reflection of the salined soil in the photographs has great practical significance. The solonchaks with salt blooms on the surface have a white tone on the photographs; the solonchak meadows are light gray, and the solonets are gray. The possibility of isolating the saline soils among the plowed fields on the photographs is very important.

In individual cases, the variation of the mechanical composition of the soils is well noticeable on the photographs. The massives of eroded, plowed and fallow fields which are characterized by a a finely striated texture of sublatitudinal orientation are decoded well. The centers of complete weathered erosion of the soil are visible in the form of white spots.

The vegetation is especially well-reflected on the photographs, and it is an indicator of those components of the landscape such as soil and in a number of cases, relief. The steppe and meadow-steppe vegetation appears on the photographs primarily only in fields which are unsuitable for plowing; therefore, the possibility of distinguishing the zonal types of grasses by the photographs is somewhat complicated.

However, the intrazonal variations connected with the characteristic features of habitation are isolated very well. This refers especially to the holophytic vegetation. The appearance among the grass vegetation of brush groups, for example, spirea along the troughs and in the dry-steppe zone is clear. The boundaries of the forest vegetation also stand out very clearly everywhere. This also pertains to the pinewoods or fir in the steppe zone and to the mountain forests and the birch groves. Howdver, the distinction of species inside butlines of the forest is not possible everywhere.

It is difficult to distinguish, for example, pine and fir forests. In exactly the same way, the sections of birch forests are not clearly isolated inside the strips of pine groves although the exchange of types of forest (in not only species) connected with the variation in habitation conditions is exhibited quite well. The clear representation of clearings helps in the use of the photographs for logging.

By the space photographs it is possible to trace the snow-ice complex in the mountains. The study of the distribution laws of the unthawed snow permits us to judge its relative thickness. Snow drifts corresponding to the direction of the snow transfer can be seen well on the photographs. The different types of snow formations are distinguished — bench, heaped, avalanche. Even small avalanche snow formations are distinguished, the type of which can be judged by the nature of the avalanches.

The ice massifs and individual glaciers are well recognized. With a 10-15 fold magnification, not only the outlines of the individual glaciers are distinguished but even the details of their suface such as morainic ridges and zones which the glaciers occupied in the recent past during the so-called fernau stage.

The space photographs can be used to compile the ice maps of the ridges. In a number of cases they permit us to correct the indirect position of the boundaries of the glaciers indicated on the topographic map.

The image on the space photographs of all components of the natural environment makes these photographs especially valuable for all-around investigation of the medium, that is, to study the natural landscapes.

Geological Interpretation of Space Photographs

The requirements on the geological study of the Earth and the special geological mapping required for scientific forecasting of minerals are growing continuously. This causes the necessity both for more profound all-around research and the use of the methods of investigation which with relative cheapness permit summary data operatively to be obtained for the large regions in order to discover the best prospective sections for the statement for detailed operations. In a number of such techniques, the primary role belongs to the use of the data from aerial photographs. The geological decoding of these materials permits an objective analysis of the available factual data, tying together of the scattered fragments of the structures discovered previously within an area into an integral whole.

However, the large amount of operating experience with respect to using aerial photographic techniques has revealed some of the deficiencies. The basic ones of these include the limited nature of the area encompassed by the photographs under uniform conditions of taking photographs. This essentially lowers the possibilities of comparing and making a comparative analysis of the individual regions. Even the use of the smallest-scale aerial photographs cannot eliminate this deficiency.

The use of photographic materials from space is free of thės deficiency and insures that information will be obtained on a qualitatively new level. Taking photographs from space stations permits us to obtain a single image of the geological and geomorphological objects of regional and even global scale with a decrease in the number of variable natural and technical factors affecting the quality of the photogfaphs to a minimum.

In all cases the space techniques are a means of obtaining important additional information forcing the researcher more objectively to evaluate the existing facts and providing data for new ideas playing an important role in the development of geology.

The results of decoding the photographs received from the Salyut manned orbital station serve as a clear illustration of the effectiveness of using space techniques for geological research.

When doing the primary processing of the photographs, primary attention was given to discovering the regional structures and studying the interrelations among them. During the process of decoding, a series of new data were obtained on the geological structure of broad territories. A significant part of them were studied by orbital photographs; in some cases, prospective photographs were used.

As the study of space photographs has demonstrated, faults and segments of development of Quaternary deposits are most clearly isolated on them. It is possible to distinguish an entire network of faults in the surface of the Earth: from the largest encompassing entire geographic regions to relatively small -ones.

When studying the sections of the Earth's crust during the Quaternary period it is possible to isolate not only the clear regions of their broad development, but also to determine the extent of these formations within the limits of individual, sometimes qūite narrow valleys even in mountain regions. In this case, the degree of detail is limited only to the resolution of the camera and the size of the investigated object. Where there is bedrock it is more difficult to decode the photographs.

It is possible to distinguish the granite massifs relatively well on the space photographs. In the regions of development of sedementary formations, usually only the structural lines are isolated which emphasize the basic folded structures. In a number of cases annular structures have been noted also.

The primary attributes on the basis of which the geological study of the space photographs has been made were the characteristic features of the structure of the relief and also the nature of the photographic representation. Thus, for formations of the Quaternary period, usually a lighter tone is typical. The granite massifs frequently form uplifts and have a network of crakks. They are distinguished by the characteristic picture of the photographic image.

The basis for studying the surface faults is in the majority of cases the sharp contrasts with the contours differing with respect to configuration and tone of the image reflecting the differences in composition of the rock. The isolation of the ancient faults on the space photographs is possible as a result of the fact that they are expressed by different linear forms of relief: elongated protrusions and depressions.

According to the photographic data from the Salyut orbital station, the relation of the peculiarities of the photographs of the geological formations to the physical-geographic peculiarities of the terrain have been established. In the lowland regions with relativelysimple geological structure, not only have sections of development distinguished with respect to age and origin been detected and the geological survey maps more precisely defined, but also very important, theoretically new material has been obtained on the structure of the beds at great depth.

The space photographs permitted isolation of the differences between the rock distinguished with respect to time and conditions of formation. An especially large amount of interesting information has been obtained on the age and conditions of development of rock.

On the photographs from space, large fields of loose deposits of different origin are clearly distinguished. Very interesting information has been obtained on types of faults in the Earth's crust and especially on the categories which the space photographs have not detected in practice by traditional methods. These are individual zones of dislocations with a break in continuity which are hidden by a surface layer of soil, but were the result of the activity of deep layers in recent times.

In the plains and mountain regions with complex geological structure, the largest amount of data when decoding the photographs was obtained on the tectonic structure.

The decoding of the space photographs by the crew of the Salyut orbital station permitted a survey map of the structural-geological structure of a broad territory to be compiled.

Along with the large faults on the space photographs, faulted zones separating the large fault systems into individual blocks are discovered. These faults correspond on the gravitational maps to the zones of maximum gradients of the gravitational field, and in the magnetic fields they appear with respect to the displacement or discontinuity of the magnetic anomaly axes.

On the space photographs it is possible also to see the details of the folded structures which are revealed by the characteristic strips. The granite massifs are determined by their position in the relief and by the light tone of the photograpic image.

The decoding -of the rock on the space photographs can have defined significance on isolation of the large regions of the lithologically uniform formations. The large fields of development of the effusives are clearly decoded by the nature of the relief and the dark tone of the image. The loose Quaternary deposits are well-decoded. By the tonal differences and the configuration of the image among them it is possible to isolate the individual large genetic types: alluvial deposits of large rivers, delta deposits and aeolian formations.

When decoding the space photographs, the elements of the faulting are most clearly revealed where it is possible to establish the presence of faults of different categories. The large zones of deep faults separating the principal structural units are well decoded. The decoding of the space photographs proved that in a number of cases the direction of the faults visible on them differs somewhat from their configusations on the existing geological survey maps. It turned out to be interesting that during decoding the large dislocations with a break in continuity within the limits of the depressions covered by the powerful cap of Quaternary deposits turned out to be very interesting.

The areas of development of the Quaternary deposits are well-visible on the space photographs. In the regions of development of these deposits it is possible to separate various genetic types. It is possible to distinguish the formation of deltas, individual proluvial cones, alluvial plains and sections of the weathered sand, and so on. The troughs of the dried lakes are distinguished well.

The Paleozoic and prepaleozoic formations are distinguished somewhat worse when decoding. However, in a number of cases it is possible to reveal granite intrusions, especially the youngest ones usually pertaining to the permian intrusive complex. Thus, the space photographs are the source of a large quantity of new geological data. Above all, this pertains to the disjunctive tectonics; the decoding dislocations with a break in continuity, the faulted and crest zones permit significant supplementing and correction of the geological maps, and this means a different interpretation of the structure of the region and, probably, more purposeful geological exploratory work.

General Evaluation of the Possibility of Using Space Photographs to Solve Scientific and National Economic Problems

A comparison of the space photographs with the data of other investigations of the natural environment reveals new possibilities which photography from space offers. All of the new elements of the landscape are reflected on the photographs. In a plains region, these are the mesorelief, the drainage system and the soil-plant cover. In the low and medium mountain regions, the large features of the relief on the first level along with the tectonic and erosion dismemberment of the territory and the alternation of vertical soil-plant zones. In the high mountains, the relief of the ridges, the intermontain faults, the large valleys emphasizing the breaks in the Earth's crust and the snow cover and glaciers are most clearly expressed. The cloud wover, including above the mountains is well-reflected.

By using space photographs, the possibility of simultaneously recording the fast processes and phenomena occurring over large territories is obtained. The agricultural subjects (especially in the lowland steppe regions of grain agriculture) were brightly reflected on the photographs. By the photographs it is possible to study the configuration of the farm lands caused by the natural and economic features and also to analyze the direction and specialization of the farms. In addition to the fields, the remaining lands are also visible — laylands in various stages of overgrowth, feed lands, forests and unusable fields. It is possible to determine the type of crop rotation and the planted fields of various farm crops.

The space photographs present rich data for compiling maps of the farm lands and evaluating the possibilities of mechanized working of the fields. They permit judgment of the system of using the ploughed fields and the agricultural system. The forested shelter belts, the farm crops, the clean fallows, perennial grasses in the crop rotation and irrigation systems can be decoded on them. The breaks in the fields planted to feed crops are visible. The differences in farming in the territory of individual and administrative-economic units are well distinguished.

The different tone of the photographic image of the fields is connected with differences not only in the crops but also in the condition of the fields. On the basis of this, it is possible to forecast the harvest of the agricultural crops, the operative times of performing agrotechnical measures and pest control measures. The problems of determining the phases of development of the plants by the space photographs require especially careful study. The same thing also pertains to the discovery of the weediness of the fields, plant diseases, and so on. An analysis of the morphological elements of the forested landscapes and the types of forests connected with them permits a basis for the forestry measures, discovery and calculation of the areas of the forests most damaged by fires, wind erosion and other unfavorable effects, establishment of the sections requiring fastening of the sand, the primary forest plantings or thinning of the forest stand. An analysis of the intralandscape structure permits establishment of an efficient type of using natural feed lands.

Thanks to the clear representation on the photographs of the drainage network and the possibilities of more precisely defining the watershed areas of individual streams by them, they present good material for selecting the locations of reservoirs. By them it is possible to make a preliminary source of the basic elements of the irrigation systems without expensive and prolonged exploration. The photographs from space are also good material for compiling numerous hydrologic maps of the watershed basins, the density of the river network, the winding nature of the rivers and as a source which the topographic maps now serve.

In addition to using the photographs for practical work to study and map specific territories, the photography of broad expanses provides material for the development of the typology of the macro, meso and microstructure of the soil cover.

The space photography improves the reliability of the available information about the natural environment and, above all, the materials from the thematic mapping of the Earth's surface. As the data from interpreting the space photographs on a scale of 1:2 million to 1:3 million have demonstrated, they can be used to revise the geomorphological, geological, hydrologic and other maps on a scale of 1:1 million to 1:5 million.

The study of all of the above-enumerated elements of the natural environment and human activity has enormous national economic significance. The meteorological weather forecasting from a study of the cloud systems, the exploration for minerals provided by geological mapping and the study of discontinuities and faulting of the Earth's crust, the evaluation of the conditions of the construction and agricultural use of lands as a result of studying the relief and erosion processes, the evaluation of the productivity of the soil, the state of the forests, the hydraulic resources, the study and forecasting of various dangerous phenomena (for example, the snow avalanches and mud flows) — this is a far from complete list of the economically important problems directly based on studying the natural characteristics by interpretation of them from space photographs.

In order to solve many of the economic problems, at the present time it is becoming necessary simultaneously to serve an entire administrative rayons, oblasts and large economic regions. The space survey gives exceptionally valuable material for studying the effect of the natural environment on the economic activity of man and the inverse process — the consequences of the effect of human activity on changing the natural environment. The utilization of these possibilities is especially valuable under the conditions of planned development of the national economy of the USSR.

Spectral Photometric Measurements of the Earth from Space in order to Study the Natural Environment

Significant information about the Earth's atmosphere and various types of underlying surface can be obtained from space by means of various optical spectral methods of investigation and visual observations by the cosmonauts. The significance of the visual observations arises primarily from the fact that by using such improved optical instruments as the human eye it is possible to determine the brightness and color of the various underlying surfaces and atmosphere, to detect objects and determine the visibility in space, to observe various atmospheric phenomena, for example, thunderstorms and lightning and to determine the brightness of the stars, moon and planets and to trace the movement of cyclones, storms and clouds.

At the present time, broad data have been accumulated for the study of our planet from space although the observations of many atmospheric phenomena are to a known degree of a random nature. With an increase in the time periods spent by the cosmonauts in orbit, the visual observations of the Earth will become more and more purposeful.

For a number of years, Soviet and American astronauts have made visual observations, and they have received black and white and color photographs of the day and twilight horizons, the Earth's surface, the cloud distribution, and so on.

Simultaneously with this, spectral measurements have been taken of the brightness of the Earth's atmosphere and underlying surface based on utilizing special spectraphotometric apparatus. They have significantly expanded the possibilities of simple photography of the Earth from space and have permitted objective evaluation of the reliability of the visual data of the cosmonauts. On the Salyut orbital manned station, the purposeful and systematic study of the Earth's surface and atmosphere have been organized by a special program which has provided for the solution of the following basic problems:

Spectraphotometric measurements of the sun and the twilight halo of the Earth's atmosphere on the various conditions of illumination, angles of viewing and different locations of the observer in space in order to investigate the brightness picture of the halo and to study the vertical aerosol structure of the atmosphere;

Spectral photometric measurements of various natural formations in order to study the possibilities of recognizing them;

Implementation of a complex program of ground and aircraft optical studies of the atmosphere and natural formations under the satellite in order to obtain data characterizing the spectral transmission function of the atmosphere, the spectra and spectral contrasts of the natural formations as a function of the basic optical parameters of the atmosphere and the underlying surface.

The synchronous experiment under the satellite has also pursued the goal of obtaining a set of radiation characteristics of natural formations in various spectral regions (from the visible to the microwave region of the spectrum) inasmuch as the use of such data is important for studying the variability of the field of reflected solar radiation and also the natural radiation of the Earth as a function of the geological-geographic features of the natural formations.

The spectraphotometric studies of the Earth's surface from the Salyut orbital station have been made by the cosmonauts by means of a manual spectograph.

The light flux was recorded on the photographic film of the spectograph sensitive in the range of 400-700 nm. In front of the slit of the instrument there was successively an entrance objective lens, a shutter and a light dividing prism which refracts a great part (95 percent) of the light flux passing through the objective and the shutter at a right angle and directs it toward the entrance slit aperture of the spectrograph. A smaller part of the light flux (about 5 percent) goes directly through a light dividing prism to the photographic film. Thus, the entrance objective of the instrument simultaneously gives an image of the photographically measured territory in the photo gridding channel and in the plane of the entrance aperture of the spectrograph.

The kinematics of the instrument provide for (on pressing the trigger of the shutter recess) changing of the neutral filters which subsequently are introduced behind the slit of the spectrograph and winding of the film. The shutter is thrown on pushing the trigger. Images of two and even more types of underlying surfaces can reach the slit of the instrument simultaneously, the reflection spectra of which are recorded on the photographic film at the time of response of the shutter. The time of taking the photograph is fixed on the film by means of brief illumination of the clock dial. The center of the crosshairs of the instrument viewer coincides with the center of the slit; therefore, the instrument can aim the slit of the instrument can aim the slit of the instrument at the most interesting parts of the underlying surface or at the boundary between two types of it.

The picture obtained on the spectrograph contains the following information. In the upper part of the frame there is a picture of the territory by which the segment of the underlying surface isolated by the instrument slit is determined; in the center there is a photograph of the clock dial. Knowing the time the photograph is taken, the orbital parameters of the coordinates of the point under the satellite, the sun altitude above the horizon and the scale of the photograph

The synchronous experiment under the saeellite with the participation of aircraft laboratories and ground research groups was performed for the first time during the group flight of the Soyuz-6, Soyuz-7 and Soyuz-8 spacecraft in October 1969. During the flight of the Salyut orbital station, two laboratory aircraft (Il-18 and An-2) were used for performing the synchronous experiment under the satellite. The experimental program included the aircraft sounding of the atmosphere in order to determine the transfer function of the atmosphere and the underlying surface at the land-sea boundary. The aircraft took off at about noon and recorded the atmospheric characteristics at altitudes of 300, 2000, 4000 and 7500 meters. In addition, the spectral albedo and spectral brightness coefficient of selected routes (measurements at altitudes of 300 and 8000 meters) were determined.

The experiment with respect to spectographic measurement of the underlying surface from the Salyut station was performed on 14 and 15 June 1971. In the region performing the synchronous experiment, the sun altitude was 10-12° above the horizon. Measurements were taken simultaneously from onboard the Il-18 aircraft.

By the measurements performed by the spectograph, the spectral brightness of different types of underlying surfaces were obtained. When determining them, the height of the sun from the horizon at the point under the satellite found by the time of taking the photograph and by the coordinates of this point which, in turn, were determined by the orbital parameters was taken into account.

The spectral brightness coefficients obtained have good qualitative agreement with the theoretically expected picture taking into account the effect of the transfer function of the atmosphere. In the shortwave part of the spectrum, the spectral brightnes coefficients increased significantly by comparison with the values of the coefficients obtained during ground measurements. This is especially noticeable for the typess of surfaces which have a small reflection factor in the spectral range. In the longwave part of the spectrum, the difference in the spectral brightness coefficients measured on the level of the Earth's surface and from space is small. The principle of recognizing the various types of underlying surface during spectraphotometric measurements is based on comparing the spectral brightness coefficients for various wavelengths and discovering the relations characteristic of the given surface.

By comparison with the spectra obtained under ground conditions, the results of the space spectraphotometric measurements of the soils and denudation of the rock have a less expressed spectral dependence. The general brightness of the soil geological formations observed from space increases. This is especially noticeable in the blue-green part of the spectrum (with a wavelength of λ = 450-500 nm) where the brightness of the atmospheric haze increases the spectral brightness by 10-15 percent and also in the green-orange part of the spectr$_{um}$(λ = 500-600 nm) where it is increased by 5-10 percent. In some cases the spectral brightness increases also in the red range with a wavelength of λ > 600 nm.

It was highly unexpected that the ecologic types of plants are clearly distinguished from space by the spectra in spite of the fact that the plant spectra obtained from space are significantly distorted by comparison with the ground spectra. The expressed nature of the "green" brightness peak drops sharply. This is explained by the superposition of the brightness of the atmospheric haze which above a surface with more or less dense vegetation always gives an increase in brightness for λ = 400 nm by about 10-12 percent.

The water surfaces spectra photometrically measured from space give higher values of the spectral brightness than the ones measured under ground conditions. The qualitative characteristics of the spectra also vary. The peak at λ = 530 nm is not expressed. It is entirely overlapped by the effect of atmospheric haze, the brightness of which at $\lambda <$ 500 nm increases by 10-15 percent.

The spectral brightness coefficients of the snow surfaces measured from space by comparison with the ground data have a less absolute value in the red zone of the spectrum. On the whole the coefficients measured from space are approximately 20 percent lower than those obtained under ground conditions. Their noticeable decrease in the space spectra at λ = 6 nm is obviously explained by the presence of discontinuities in the clouds and the effect of the light-shadow structure of the cloud field surface.

Experiments performed during flights of the Soyuz spacecraft and the Salyut orbital station convincingly demonstrate that the spectral investigations of the brightness field of the Earth can be an effective means of studying the natural environment and natural resources from space. The primary prospects for the solution of these problems connected with using automated equipment and complicated devices requiring constant monitoring on the part of a human are implemented best of all onboard the manned orbital station.

The broad possibilities for remote sounding of the natural environment by means of special spectraphotometric equipment installed onboard the orbital stations permit the hope that in the near future it will be possible effectively to solve the most varied problems beginning with the determination of the high-altitude behavior of the aerosol scattering coefficient and ending with mapping the entire Earth for a very short time interval. During remote study of the natural environment from outer space, many urgent problems having significance to the economic activity of man will be solved on the scales of nations and continents.

The directional and systematic study of the Earth's problems from spacecraft has still only just begun. In order that the prospects for using the space methods of studying the natural environment become a reality, it is necessary to have a broad complex of ground, aircraft and space experiments.

Testing the Station Equipment and Control Systems

During the process of scientific-technical experiments on the Salyut orbital station, individual instruments, equipment and station control systems were checked in order to perform more complicated programs and studies in the future. The conditions of the operation of maintenance of the instruments in outer space differ significantly from the conditions of the operation and maintenance of ground equipment. Therefore, it is very important to know the operating peculiarities of the equipment in space in order not to permit distortions of the results of the scientific experiments. The work of the instruments under space conditions is affected by the special thermal conditions, weightlessness, deep vacuum, and the effect of radiation and light noises.

The technical experimentation program using the Salyut station provided for the study of the state and quality of the ports, determination of the visibility conditions and corditions of recognizing stars both on the "day" and on the "night" parts of the orbit; determination of the level of the light noise by the method of visual observation by the cosmonauts and using automated instruments, the processing and further improvement of the instruments and methods of controlling spacecraft during orbital and inertial orientation of the station; the study of more exact characteristics of the optical and gyroscopic instruments and also determination of the station deformation and the detuning of the equipment in flight.

Investigation of Ports

The ports of the spacecraft provide normal temperature and atmospheric conditions in the living and instrument compartments. Almost all of the visual studies and photography of the outer space are done through the ports. In some cases also very thin spectrometric studies are done through the ports. It is obvious that any unrecorded change in the state of the ports can lead to the reception of false information as a result of distortion of the picture observed through the port.

In flight the port can become dirty as a result of condensation of various materials on its inside and outside surfaces. Some change in the state of the surface of the ports is possible also as a result of the effect of the residual atmosphere, erosion, and so on.

It must be noted that the thinnist film of material on the surface of the surface of the port sharply worsens its characteristics. Thus, for example, for a number of astrophysical observations, distortions of the surface of the glass of no more than a quarter of a wavelength of the instant light are admissible. Therefore, the application of a material with a thickness of 0.1 microns is inadmissible. Thus, with a port diameter of 250 mm, the distributed mass of the material incident on the surface of the glass must not exceed 5 mg.

The quality of the ports has especially great significance when observing weak radiation sources. In the given case, the contamination of the ports is dangerous not only because the energy losses increase but also as a result of scattering of the light from more powerful sources. The significant contamination of the surface of the ports of spacecraft occurs under the effect of a powerful radiation source such as the sun.

It is known, for example, that for a defined background brightness it is impossible to observe stars with the naked eye with a brilliance weaker than +4.00 stellar magnitudes used for orientation. However, the creation of a port which does not introduce spurious illumination and retains its characteristics under the conditions of space flight is a complex engineering problem. If it is necessary frequently to be protected from the solar radiation by means of special blinds, covers and such devices, or protection from the Earth's radiation during orbital flights it is significantly more difficult as a result of the large angular dimensions and the necessity for viewing a number of weak sources of radiation directly near the Earth's horizon.

Under ground conditions, the ports are subject to a large cycle of tests; however, the correctness of the calculations and the measures taken with respect to maintaining the port characteristics under the conditions of space flight as a result of an enormous number of active factors can only be confirmed by a direct experiment. The series of such experiments was carried out on the Salyut station. Permanent monitoring of the condition of the port surfaces was carried out, the scattering coefficients of the individual surfaces were determined by means of special radiators, a study was made of the dependence of the state of the ports on their position with respect to the possible sources of contamination, the effect of the thermal regime on the optical surfaces was checked, the nature of the formation of the contamination in the form of deposits, individual particles, drops, and so on was checked. The dimensions of the cavities occurring during the impact of micrometeorites on the outside surfaces of the port glass were recorded, the effect of the thermal conditions on the glass surfaces and on the accuracy characteristics of the ports using a special measurement cycle was determined.

In order to determine the errors introduced by the ports, a comparison was made between the values of the angular distances measured through the ports by a precision navigation instrument between the heavenly bodies with known (tabulated) spacing. By this method it is possible to determine the errors of the ports in different cross sections with an accuracy to units of angular seconds.

The observations made by the cosmonauts during flight and the control photographs made by them in flight basically confirmed the effectiveness of the adopted measures with respect to insuring stability of the port characteristics.

Study of the Conditions of Visibility and Recognition of Stars

In order to realize high-precision three-axial orientation of a space ship in space during aiming of the research apparatus, for example, telescopes, at given sections of the stellar sky it is convenient to use individual stars and groups of stars as the reference points.

The execution of such methods of orientation with the participation of astronauts requires preliminary determination of the conditions for which quite reliable observation and recognition of the stars are possible. Here, it is necessary to study the effect of the conditions of illumination of the ice-caps by the sun, the brightness of the outer and inner light sources, the dimensions of the field of view during recognition of stars, the characteristics of the instrument equipment, the level of light interference from the spacecraft engines and so on. The psychological state of the cosmonaut during flight and the level of his training in stellar recognition also has great significance.

The cosmonauts G. T. Dobrovolskiy, V. N. Volkov and V. I. Patsayev performed a number of experiments and observations with respect to recognition of stars both in the both in the Earth's shadow and under the conditions of illumination of the station by the sun. The stars were observed through the port protected at this time from direct solar radiation.

In certain experiments the cosmonauts could use stellar maps for recognition and an onboard stellar globe; in other experiments the recognition was exclusively by memory.

The experimental results obtained confirmed the possibility of observing the stars by the naked eye and recognition of them under "daylight conditions." The cosmonauts positively observed the constellations in the "day" part of the orbit of the station.

The observations of the recognized stars under "night" conditions confirmed the high resolution and threshhold sensitivity of the visual apparatus.

The experiments performed permit more precise definition of the requirements on the characteristics of the visual optical instruments and improvement of the methods of maintaining precision orientation regimes of the manned spacecraft.

Determination of the Light Noise Level

The study of light noise accompanying the flight of a spacecraft has been given a great deal of attention in connection with the fact that this noise camouflages the reference points selected for orientation or in a number of cases they can simulate them. It is natural that this can cause disturbances in the operation of the spacecraft control systems or distort the scientific information.

During the flight of the Salyut station, its crew was charged with tracing the light phenomena arising in the vicinity of the station. The cosmonauts visually determined the level of the distributed and pseudopoint light interference. They performed an analysis of the variation of the number depending on the operating conditions of the station systems.

The mission of the cosmonauts also included determination of the angular and linear rates of displacement of the individual particles, recording their trajectories, recording and analyzing the relative brightness, color and twinkling rate, and so on.

The cosmonauts compared the light engineering characteristics of the particles under conditions of illumination of the station by the sun and also in the twilight zone and when flying in the Earth's shadow.

The cosmonauts' observations essentially filled out the information on the light interference near the station. The visual observations by the cosmonauts were supplemented by measurements of the level of light interference using a photometer. This complex experiment permits evaluation of the measurements and observation in the absolute system of units. As a result of the studies made it was possible to establish both the maximum level of light noise for the given type of station and the operating conditions of the station when this noise was in practice was absent.

The information obtained by the first testers of the station on the light interference will permit not only definite improvement in the onboard equipment operating with respect to sources of low-density radiation but also the development of recommendations for selecting the time and the method of maintaining the orientation regimes of the station when performing scientific experiments on subsequent manned orbital stations.

The Development of Instruments and Methods of Controlling the Spacecraft

The appearance of a new instrument in the composition of a spacecraft system is preceded by a long cycle of terrestrial development. The ground development includes testing the fitness of the apparatus with the maximum possible approximation to the spaceflight conditions. However, the most complete check still can be done only onboard the spacecraft under real flight conditions. When testing the apparatus on unmanned spacecraft in the automated mode, the research is performed by a rigid time program and it is in the majority of cases impossible to change it during the process of the flight. Therefore, it is very important to perform the flight tests of the experimental apparatus on the manned spacecraft when the test engineers are operating with it.

The aparticipation of cosmonaut in the testing of new instruments as the person conducting the experiment permits an increase in quality of this test, the study of various aspects of the operation of the apparatus and, when necessary, flexible variation of the experimental program without increasing the time allotted to it.

The telemetric information on the operation of the instrument and the visual observations of the cosmonauts provide the basis for evaluating the fitness of the apparatus of the spacecraft system. The performance of the flight tests is especially important for various instruments of the cosmic orientation system using the sun and stars.

The most interesting test is the test of the orientation of the instruments with respect to the stars and aiming the solar sensors at the sun as the reference point presents no difficulty. The crew of the Sâlyut station tested several methods of aiming the stellar orientation instruments at the given reference point. This experiment along with the basic control instruments included the following scientific apparatus: the tested stellar sensor, the control panel with indicators and displays for monitoring the operation of the stellar sensor, a visual sighting device, the reckoning grid of which is parallel to the optical axis of the stellar sensor.

Depending on the preliminary conditions of orientation of the station in space by the cosmonauts of the orbital station, ~~one version~~ of the exit to the desired reference point was selected. These versions provided the possibility of detection, recognition and aiming of the tested instrument on the given star for various orientation conditions: during rotation of the station around the axis directed toward the sun, during orbital orientation of the station or during arbitrary positioning of its axes in space. Each version had its range of application. Thus, for example, the search for the star during rotation of the station around the axis aimed toward the sun permitted sufficiently reliable recognition of the star and aiming of the tested instrument on it during daytime conditions for significant light interference levels.

The results obtained by the station crew when testing the apparatus can be successfully used both for automated optical orientation instruments of any type — stellar, planetary and solar sensors of the control system of any spacecraft — and for sighting the scientific equipment — telescopes, spectrometers and so on — on the measured subject.

ON the Salyut station, the crew performed tests in space and on new instruments designed for manual orbital and inertial orientation of the spacecraft. The complication of the spacecraft control problem requires further increase in accuracy of orientation and optimization of the search regimes and an increase in the instrument reliability. However, the accuracy of the orbital orientation of the spacecraft from the ground is limited to such objective factors as the atmosphere, cloud formations at different altitudes, the nonspherical nature of the Earth, and so on.

Therefore, during flight the cosmonauts performed comparative tests of the orbital orientation instruments in order to determine their instrument accuracy and convenience in operation. Here, the data from visual orbital orientation of the station using optical instruments with different power and field of view, with different flight engineering characteristics were compared with the readings of the automated instruments for orbital orientation.

The cosmonauts G. T. Dobrovolskiy, V. N. Volkov and V. I. Patsayev noted the great possibilities of the wide-angle viewer for both orbital and inertial orientation. This instrument is especially convenient when performing various maneuvers of the station with respect to the direction of the sun.

The precision visual instrument for constructing the local vertical using the differential method of determining the mismatch angle also received a positive evaluation from the crew. In the opinion of the cosmonauts, the instrument permits an increase in the orbital orientation accuracy by several times.

In flight, the station testers developed an instrument for visual orientation of the spacecraft on groups of stars with high accuracy. Here, during the process of the experiment it was necessary for the cosmonaut not only to recognize the stars and combine them with special marks in the field of view of the instrument but also to execute complex maneuvers with respect to optimal control of the station on making the transition from one constellation to another. They compared excellently. The control units of the instrument suspension permitted objective the evaluation of the accuracy and stability of the orientation maneuvers performed by the cosmonauts.

When developing the method of navigational measurements onboard the orbital station, in addition to the high-precision goniometer the cosmonauts used a medium accuracy class sextans. However, this instrument did not receive the approval of the cosmonauts.

Study of the Accuracy of the Instruments and Systems under Flight Conditions

Onboard the station for the performance of various regimes connected with the control of the orbital space station and also for the execution of the scientific and technical experiments, various precision instruments were installed -- optical and sterioscopic sensors, telescopes, and so on. The placement of these instruments on the station must be mutually connected, that is, the position of the sensitive elements of the instruments with respect to the station axes must be strictly defined, and the possible mismatch between the instruments under flight conditions must not exceed the admissible values.

The complexity of matching consists in the fact that the precision apparatus is installed for operating convenience in different compartments of the station since the placement of the apparatus on a single power element does not seem possible.

The flight experiment onboard the Salyut station was carried out by the following scheme: using the station orientation system, the solar and stellar sensors were aimed on the reference points -- the sun andthe stars. One solar and stellar instrument each participated directly in controlling the motion of the station around the center of mass. The remaining instruments were included in the so-called telemetric regime when the information about the deviation of their sensitive axes from the direction of the sun and star was not used in the control system but only recorded for further analysis.

After some time sufficient for the transition to the steady state orientation mode, the station control was transferred to the recording gyroscope, and the solar and stellar sensors actively participating in orientation were also converted to the telemetric mode. The screens of the viewing instruments with representations of the heavenly bodies were photographed synchronously.

An analysis of the information received from the Salyut crew taking into account the results of the preliminary ground measurements of the accuracy of the optical instruments and the orientation systems permitted us to obtain instruments of the mismatch of individual instruments under flight conditions under the effect of a number of factors of space flight on the station (vacuum, weightlessness, and so on) and also evaluation of the accuracy of the optical and gyroscopic instruments during flight.

The results obtained were used not only to make several corrections to the accuracy of the instruments during flight of the first orbital station.

They will have great significance also for subsequent flights of spacecraft. The results of the inflight experiment on the Salyut station will permit more precise definition of the dimensions of the fields of view of the individual optical instrument and the radiation patterns of the radio telescopes. All of this will promote a significant increase in reliability of the instruments under space flight conditions.

Testing the Autonomous Navigation Systems

The Salyut scientific station was equipped with an experimental autonomous navigation system. By using this system the cosmonauts measured the position of the station in space relative to the sun, the Earth and ground reference points. All the required calculations of the orbital parameters were made on a special onboard digital computer.

By using the autonomous navigational system, the test engineer of the station V. I. Patsaye took some navigational measurements. He determined the elements of the station orbit and the data for forecasting the movement. He calculated the required maneuvers and the orbital corrections. He determined the data for the control system by the orbital corrections and gathered ballistic information (the time of the beginning and end of radio communications with the Earth, the time of emergence the shadow and going into it, the times of intersection of the equator, the terminator, and so on).

The instrument composition of the navigational system permitted automatic determination of the times at which the station entered the shadow and left it, measurement of the flight altitude of the station above the Earth's surface, determination of the angular spacings of the ground reference point with respect to the local vertical, and calculation of the angular altitude of the stars above the Earth's horizon.

The information from the measuring instruments reached the onboard digital computer on which the entire volume of necessary calculations was performed. The navigational measurements included the following regimes.

Sun Regime. The work in this regime did not require the special orientation of the station. The measurements of the times of sunrise and sunset were automatically stored and processed on the onboard digital computer. These measurements permitted determination of the orbital period, the longitude of the ascending node and the time of its passage. In addition, by varying the period of events it was possible to determine the dynamic state of the atmosphere, and at the same time, the rate of descent of the station and the time of its existence.

Altitude Regime. In this regime, measurements of the dynamic altitude of the station above the Earth's surface were performed. During the measurement process the station was oriented on the local vertical. In order to eliminate error which could be caused by relief of the Earth, measurements were taken over the ocean surface. By the altitude measurements the dimensions and the form of the station orbit and also the time of passage through its pericenter were determined. The altitude measurements over a prolonged period of time permit determination of the dynamic state of the atmosphere.

Landmark Regime. In this regime a triaxial orbital orientation of the station (by the local vertical and by the heading) was realized, the terrain was recognized in nature and the angular spacing between the local vertical and the ground reference points with simultaneous measurement of altitude was carried out. The characteristic details of the Earth's surface such as the branching of rivers, small islands and lakes and parts of the shore line were used as the ground landmarks. By these measurements, generally speaking, all of the orbital elements can be determined; however, in order to increase the accuracy the dimensions and shape of the orbits are determined by the measurements in the altitude regime and only the position of the plane of the orbit and the time of passage of the angle are determined by the measurements in the reference point regime.

Star Regime. In this regime a sextant was used to determine either the angular spacing between the horizon of the Earth and the direction of the star or the time of setting of the star behind the Earth's horizon was recorded. The measurements with recording of the times of setting of the stars are more exact and more convenient, but they require large expenditures of time since it is necessary to wait for the time when the star approaches the horizon.

The measurements in the star mode with a sufficient number of stars and favorable arrangement of them permit determination of all elements of the orbit.

After the navigational measurements were taken, test engineer V. I. Patsayev solved the problem of defining the orbit by the algorithms especially developed as applied to the indicated composition of the measurements and the mission of the orbital station. The navigational algorithms had to provide the following: high speed, maximum automation of the solution, reliability and noise resistance, compactness, and maximum accuracy of solving the navigational problems.

The disturbing forces occurring as a result of the noncentral nature of the Earth's gravitational field were taken into account in constructing the algorithms. Here only the first harmonic of the gravitational disturbing potential was considered under the assumption that the atmosphere affects only the sizes and shape of the orbit. In order to define the orbit of the Salyut station by navigational measurements, an algorithm was constructed so that the complete problem of determining the movement could be divided into a number of separate problems of smaller dimensionality. This permitted an increase in reliability and speed of the algorithms. When determining the orbital elements, the method of accumulation of measurement in special matrices was used. This permitted avoidance of the restrictions imposed on a number of measurements by the ready-axis memory signs of the onboard digital computer. The statistical processing was carried out by the method of maximum similarity.

The movement of the orbital station was forecasted by finite formulas (without numbrical integration of the motion control). At the given point in time, the elements of the orbit, the geographic coordinates of the station and its altitude above the Earth's surface were determined.

The results obtained confirm the correctness of constructing an autonomous navigation system and indicate the prospectiveness of the developed system. New means of manual and automated control of the motion of spacecraft were tested in flight which have great significance for the planning and design of new spacecraft and orbital stations.

Study of High-Frequency Secondary-Electron Discharge under Ionospheric Conditions

By high-frequency secondary-electronic resonance discharge, the physical process is understood for which in a high-frequency electric field in a vacuum an oscillating volumetric charge is excited between the electrodes which is formed as a result of the secondary electron emission from the surface of the electrodes.

The results of the studies performed in ground laboratories provided a basis for assuming that this process is possible in high-frequency electric fields created by the antennas of spacecraft. The occurrence of secondary electronic discharge could have an effect on the reduction of the high-frequency power and worsening of the characteristics of the antenna systems.

However, the impossibility of sufficiently complete simulation in vacuum chambers of the conditions of outer space and the effects created by the movement of the spacecraft did not permit the researchers to draw definite conclusions regarding the existence of such a process under the conditions of actual flight in space on the basis of ground experiments. Therefore, on the Salyut station an experiment was set up for experimental detection and study of the phenomena of resonance discharge under natural conditions with simultaneous measurement of the charged particle concentration in the ionosphere. The latter is necessary for more complete understanding of the results of investigating the resonance discharge, and it is also of independent scientific and practical interest. For example, this has significance for the development of ion sensors for orientation systems and certain other instruments.

The direct participation of the astronaut in the experiment permitted the application of the apparatus and execution of the research program designed for his active, creative participation. The apparatus permits variation of the experimental conditions within broad limits and visual monitoring of a number of parameters.

The astronaut can actively intervene in the course of the experiment and change the regimes as a function of the observed results.

The investigation of the resonance discharge on the Salyut orbital station was carried out by cosmonaut V. I. Patsayev. The apparatus for this experiment had three types of electrode systems. The forms of the electrodes were analogous to the forms of the antennas used on the spacecraft. The electrode systems could be connected by a special switch to the controlled attenuator regulating the level of the signals coming from the generator. The generator shaped the high-frequency pulses with a carrier frequency of about 130 megahertz, a duration of threemmicroseconds and a recurrence rate of 12.5 kilohertz. The pulse power of the generator was about 300 watts. It could be regulated smoothly by the attenaator within the limits of 0-13 decibels. The special sensors recorded values of the incident and reflected power. A direct voltage could be applied to the electrodes from the source with step regulation within the limits from -150 to +150 volts.

In order to discover the distribution of the high-frequency field near the electrodes and to control the variation of the field on the occurrence of discharge, a high-frequency sonde was used -- a receiver with two small antennas (a frame and a symmetric vibrator) installed on a rod which could be deflected by different angles.

The ion concentration was measured by three spherical ion traps. One of them was installed on the inclined rod, and the other two, on the hull of the station in a stationary fashion. The potential of the external electrode of the trap was established by the person performing the experiment (in one of the modes it varied according to a sawtooth law). Recording the collector current on variation of the grid potential, it is possible to obtain the volt-ampere characteristics which then will help find the values of ion concentration.

The control of the apparatus was concentrated in a separate unit. The parameters were controlled by several methods. All of the measured parameters were recorded on the film by a small loop oscillograph; the values of ahaumber of the parameters could be obsevved on pointer indicators and the screen of the cathode ray tube (on the face panel of the control unit). In the apparatus provision was made, in particular, for the "cyclic regime" for which after preliminary assignment of the desired regimes the measurement cycle with respect to the given program was automatically carried out.

In all there were 202 series of measurements (in each series from one to several tens of cycles). Here, the high-frequency electrodes and ion traps were shaded by the hull of the station from direct illumination by sun beams, and the photoemulsion was absent from these electrodes and the trap grids.

One of the basic results of the experiment performed is the first experimental detection of resonance discharge on electrodes installed on the surface of a spacecraft during its flight in the ionosphere. Oscillograms were obtained which characterize the occurrence of resonance discharge and define its parameters under various conditions. It was also possible to investigate (in a series of 20 measurements) the effect connected with the falling of the electrodes in the gas-dynamic shadow of the station.

The concentration of positive ions was measured in several flight sections. In spite of some lack of normalcy in the work of the sonde amplifiers, satisfactory recordings of the sonde characteristics were obtained in a number of sections. For example, on 16 June 1971, the measurements were made of the concentration of positive ions in the orbital section about 3,000 km long and at altitudes of about 250 km in the latitude range from 40 to 50 degrees south latitude.

The use of special equipment controlled by the astronautsfor direct measurements of complex physical processes in space permitted us to obtain important information about the phenomena of the high-frequency secondary-electronic resonance discharge, the distribution of the particles near the station, its hull potential and certain other phenomena under the conditions of the ionosphere.

Determination of the Dynamic Characteristics of Motion of the Station with Respect to the Center of Mass

One of the basic problems which were solved when performing scientific and technical experiments was determination of the dynamic characteristics of motion of the orbital station with respect to its center of mass. For this purpose, photographs of the stars were used.

The usually used methods of determining the actual dynamic characteristics of motion of the spacecraft with respect to the center of mass based on orientation with respetttoo individual characteristicsreference points have essential deficiencies. In particular, these methods do not permit determination of the spatial position of the object at any point in time. They are characterized by insufficiently high accuracy of solving the problem, and so on. These deficiencies are eliminated when using a natural geodetic grid with a large number of reference signs for orientation of the selestial sphere.

For determination of the angular position of the orbital stations by the stars in space, a stellar camera was used with a focal length of 212.30 mm and an operating format of the photograph (a diameter) of 128 mm. The range of photographic intervals was 4-60 seconds, and the exposure time was 0.26 seconds.

The camera was equipped with a clock the readings of which were recorded on each picture which permitted exact determination of the photography time. The optical axis of the camera was directed along the y-axis.

The calculated orientation of the camera along all three axes is determined by the star photographs. On the basis of the calculations, the required accuracy of determining the stationary orientation and the dynamics of the variation of this position in various modes, the necessary intervals of photographing the stars were calculated so as to obtain a complete picture of the dynamic processes of the stationary orientation.

The stars were photographed in three different orientation modes with respect to dynamics -- with automatic stabilization on gyroscopes, with manual orientation of the station by the astronauts and in the mode of stabilization of the spatial position of one of the axes of the station by rotation (turning).

On the photographs made in the first mode, the stars were depicted in the form of spots. Measurement of the angular dimensions of the spot and also analysis of the extremal values of the equatorial coordinates permit determination of the amplitude of the autooscillations of the stabilization system, the angular velocities in the loops and deviations of the vector of the kinetic moment of the gyroscope. Representations of the stars α Centaur (stellar magnitude $m = +0.1$), ε Gentaur ($m = +2.3$ and the planet Jupiter ($m = -2.1$) were obtained in this mode.

When analyzing the photographs taken in the second regime, it was established that the angular rate of displacement of the stars in the field of view of the camera reached 0.4 degrees/sec. In this regime, images of the stars α-Lyra ($m = 0.0$), γ-Cygnus ($m = +2.2$) and the planet Mars ($m = -1.2$) were obtained. The construction of the trajectories of the traces of the station axes on the stellar sphere offered the possibility of obtaining objective estimates of the quality of piloting the station in this regime.

The study of the photographs made in the turning regime permitted determination that the actual axis of rotation of the station was with a calculated angle of 10 degrees. This offered the possibility of drawing conclusions regarding the magnitudes of the centrifugal moments of inertia of the station. In the turning regime, images of the star α-Scorpius ($m = 0.9$) and the planet Jupiter were obtained.

By using photographs it is also possible to determine the maximum and the mean angles of deviation of the solar cells with respect to time from the direction of the Sun and the angular precession rate and characteristic rotation of the station which is important for calculating the electric power and orientation systems.

The recognition of the images of stars was realized by merging of the photographs with the map of the sky prepared on the scale of these photographs. For automation of the recognition process, an algorithm is developed which is based on the merging of the photographs obtained with respect to measurements of the angular distances between the images of the stars with a catalog of the angular distances between the stars stored in the memory of the onboard digital computer. For execution of this algorithm the false images of the stars were rejected simultaneously with recognition.

The determination of the orientation of the station by the photographs obtained was made in accordance with the procedure developed at the space research institute of the USSR Academy of Sciences. As a result of the photogrammetric processing of the photographs, schematics of the arrangement of the stars on the celestial sphere and the characteristics of variation of orientation of the station in space flight under various dynamic conditions were determined.

The calculated values of the mean square errors in determining the orientation of the station with respect to all three of its axes confirm the high accuracy of the discussed method.

The determination of the law of variation of the angular position of the spacecraft with time offers the possibility of complete investigation of the dynamics of spherical motion. The method used on the Salyut station is distinguished by good clarity, and it turns out to be useful not only for investigation of the actual technical characteristics of the systems but also when solving certain theoretical problems.

Conclusion

The first manned orbital station Salyut in the world is opening up a new phase in the development of cosmonautics -- the step of mastery of outer space by means of scientific laboratories operating for a long time in Earth's orbit with a crew of research astronauts onboard.

The flight of the Salyut station gave the first experience in the creation and functioning of heavy spacecraft of the new type. It permitted valuable data to be obtained on the possibility of a prolonged stay of man in space doing work. It demonstrated the broad range of possibilities of orbital stations -- from investigation of the natural environment and Earth resources to astrophysical studies of the processes on distant stars in the depths of the universe.

The results obtained from thesscientific and technical studies are quite broad. Processing and analyzing them are still not complete, but the data investigated, part of which is presented in this book, indicate the great scientific and practical value of the experiments performed.

Medical-biological and astrophysical research play an important role in the large volume of scientific work performed by the crew of the Salyut station. The complex photographic experiment is also important which belongs to one of the most urgent areas of applied use of kosmonautics -- investigation of the external environment and natural resources of the Earth. The materials obtained clearly indicate the high efficiency of space photographs in solving many scientific and national economic problems.

The first experiment in extraatmospheric astronomical research using the Orion stellar telescope controlled by the operator and the investigation of cosmic rays using a photoemulsion module then delivered to the Earth in a transport spacecraft, a number of scientific and technical experiments with respect to developing systems and units under natural conditions required for the planning and design of spacecraft are of great interest.

The special role of medical-biological research performed onboard the Salyut is determined by the theoretical significance for the development of cosmonautics of the problem of prolonged staying and working of a human under spaceflight conditions. The set of media for compensation for the deficiency of physical load on the organism of the astronauts under the conditions of weightlessness was tested on the station for the first time. This set of devices included the running track, the weighted suits and certain other elements. The biological experiments performed by the astronauts were directed toward solving a number of problems connected with the creation of closed ecologic life support systems for the spacecraft of the future.

The flight of the Salyut station made a great contribution to the development and improvement of space engineering. It was the first experiment in world cosmonautics in the creation of long-term orbital stations. It is clearly demonstrated theirdgreat possibilities as multipurpose space laboratories capable of effective solution of many urgent problems in the interests of mankind.

SALYUT STATION WITH CREW IN ORBIT

DOCUMENTS, INFORMATION, LOGS, TELEVISION REPORTS, RADIO CONVERSATIONS

6-30 JUNE 1971

6 JUNE

TASS REPORT

In accordance with the program for studying the space about the Earth, on 6 June 1971 at 0755 hours Moscow time a booster rocket with the Soyuz-11 spacecraft was launched in the Soviet Union. At 0804 hours the Soyuz-11 spacecraft was inserted into the calculated Earth satellite orbit.

The spacecraft is manned by a crew made up of the ship Commander Lieutenant Colonel Georgiy Timofeyevich Dobrovol'skiy, Flight Engineer, hero of the Soviet Union Cosmonaut of the USSR Vladislav Nikolayevich Volkov and Test Engineer Viktor Ivanovich Patsayev.

The purpose of the flight of the Soyuz-11 spacecraft is a continuation of the complex scientific-engineering studies in joint flight with the Salyut orbital scientific station.

Continuous radio and television communications are being maintained with the crew of the Soyuz-11 spacecraft.

The cosmonauts feel good, the onboard systems of the Soyuz-11 spacecraft are operating normally, and the given conditions are being maintained in the living compartments of the spacecraft.

Cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev have begun the execution of the planned fli-ht program.

Flight Control Center, 6 June 1971. The Soyuz-11 spacecraft completed 6 orbits around the Earth at 1600 hours. Cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev are continuing to execute the planned flight program. During this period stable radio communications have been maintained with the spacecraft, and television transmissions have taken place periodically.

According to the telemetric data and the reports from the cosmonauts, all the onboard systems of the spacecraft are operating normally. In the crew compartment and the orbital compartment the temperature and pressure are holding within the given limits, and they are 22°C and 770 millimeters of mercury respectively. The cosmonauts feel good.

In accordance with the flight program at 1350 hours a correction was made to the orbit of the Soyuz-11 spacecraft by manual navigation. According to the trajectory measurement data, the parameters of the orbit after correction are as follows:

Maximum distance from the Earth's surface (apogee) 217 kilometers;

Minimum distance from the Earth's surface (perigee) 185 kilometers;

Time for one orbit around the Earth 88.3 minutes;

Inclination of orbit 51.6 degrees.

From 1540 hours on 6 June to 0130 hours on 7 June, the Soyuz-11 spacecraft will orbit outside the zone of radio contact with the territory of the Soviet Union.

During this time the cosmonauts will rest.

From the Journal of G. T. Dobrovol'skiy

6 June 1971, 082457 hours. This part of insertion went normally. The movement is stable. All of the vibrations and oscillations feel excellent. The oscillations are small. Before separation of the last stage the G-loads increased. Then a bang and immediately quiet; there is light in the cabin. The clock and Globus[1] are not starting immediately -- after a few seconds.

Immediately after separation there was much dust. It was collected best with the fan running using a wet towel. From time to time the fan grating bends inward and the blades hit the grating. The fan was shut off and the grating bent outward with the fingers. The clicks of the operative telemetry commutator can be heard ... Contact has been made with the Earth twice.

At 114335 hours, a TASS report was heard on the insertion. Onboard everything was in order. Everyone felt normal. After separation the feeling of discomfort consisted in the fact that it felt as if someone were trying to pull your head off your neck. There was a feeling of muscle tension under the chin, heaviness of the top of the head and the back of the head seeming as if someone were pulling upward and inward by the head. When securing the body in an armchair this phenomenon decreases, but it does not go away. In this case the front and back of the head are heavy. The stomach seems to pump upward.

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[1]Instrument for stellar navigation of spacecraft.

Movements of the hands, a feeling of everything with which you work, the dynamics of the entire body -- you become accustomed to immediately.

7 JUNE

TASS REPORTS

In accordance with the program for the creation of long-term orbital stations in the Soviet Union, on 7 June 1971, the Salyut orbital scientific station began to function as the first manned orbital scientific station.

At 1045 hours Moscow time after a successfully executed docking of the Soyuz-11 transport spacecraft with the Salyut scientific station which was inserted into orbit on 19 April 1971, the crew of the Soyuz-11 space ship was transferred to the scientific station.

The engineering-technical problem of delivering a crew by transport ship to the scientific station -- an Earth satellite -- was solved for the first time.

Flight Control Center, 7 June 1971. The first manned Salyut orbital scientific station continues its flight. At 1700 hours Moscow time the station had completed 800 orbits around the Earth of which 6 were made with the Cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev onboard.

According to the trajectory measurement data, the parameters of the station orbit are as follows: the maximum distance from the Earth's surface (apogee) 249 kilometers; minimum distance from the Earth's surface (perigee) 212 kilometers; time for one orbit around the Earth 88.2 minutes; inclination of orbit 51.6 degrees.

According to the data on telemetric measurements and the report of the station Commander G. T. Dobrovol'skiy, all of the onboard systems of the station are functioning normally, and the state of health of the cosmonauts is good. The pressure in the living compartments is 900 millimeters of mercury, and the temperature is +17°C.

The Salyut manned scientific station continuing to move in the calculated orbit at 1515 hours on 7 June left the zone of radio contact with the territory of the Soviet Union. The last radio communication with the orbital station planned for the day was started at 1624 hours. It was carried out via the scientific research ship of the USSR Academy of Sciences Akademik Sergey Korolev in the Atlantic Ocean and the Molniya-1 communications satellite. From the end of that session to 0100 hours on the night of 8 June, the cosmonauts will rest alternately.

From the Journal of G. T. Dobrovol'skiy

7 June 1971. Vadim and I slept head down in the sleeping bags in the orbital compartment. Viktor in launch apparatus, across the seats also in a

sleeping bag. We slept less than usual (from 1830 to 2400 hours), but it seemed as if we had slept enough. After the inverted position, our heads again began to "fill up."

Vadim and I looked in the mirror and then at each other and laughed: "mugs like bulldogs." They raised Viktor and held a communications session. Onboard everything was in order. Vadim proposed that we wipe ourselves with wet towels. After "bathing," we set to work. At 0248 hours on arriving at the equator from the direction Antarctica we heard music.

... at 072000 hours, preparations (for docking -- Ed.).

At 0724 hours rendezvous started ... We saw the station in the optical viewer before going into the "preparation for rendezvous" mode ...

After (inclusion of -- Ed.) "the rendezvous mode" the ship began to roll energetically -- heeling, pitching and yawing.

Before (a distance of -- Ed.) 150 meters the ship equalized with respect to bank and was in practice in the center (of the viewer -- Ed.).

Manual docking was started at 100 meters. The speed was 0.9 m/sec ... On switching to manual docking the station took off to the right ... I began to extinguish the side ...

... It seemed that the left-hand lever was not adequate and I switched on the right-hand lever. I brought the ship up and to the left a little ... and killed the "lateral velocity" with the left-hand lever. At (a distance of -- Ed.) 60 meters I decreased the speed to 0.3 m/sec ...

... For the first maneuver ... there was just enough time ...

... Contact, mechanical lockon ... took place simultaneously at 074915 hours. The object did not in practice fluctuate. At 075530 hours, docking. There were no oscillations or rolling of the object. Contact, in practice, was not felt ...

8 JUNE

Flight Control Center, 8 June 1971. The second working day of the Cosmonauts Georgiy Dobrovol'skiy, Vladislav Volkov and Viktor Patsayev onboard the first manned scientific orbital station, Salyut, began at one o'clock at night on 8 June. At that time the station had entered the zone of radio contact with the territory of the Soviet Union. After resting and eating breakfast the crew proceeded with further checking and preparation of the station apparatus to perform the planned studies.

The cosmonauts tested the operation of the onboard vital support systems in the various modes. In the radio communication sessions the cosmonauts more than once noted the comfort and large size of the living and work compartments of the station. The specialists at the flight control center observed the activity of the cosmonauts using a television system.

At 1310 hours Moscow time, the crew transmitted a greeting to the people of the Soviet Union.

In accordance with the flight program at 1102 hours on 8 June a correction was made to the orbit of the Salyut station. The station was moved to a higher orbit, the parameters of which were as follows:

Maximum distance from the Earth's surface (apogee) 265 kilometers;

Minimum distance from the Earth's surface (perigee) 239 kilometers;

Time for one orbit around the Earth 89 minutes;

Inclination of orbit 51.6 degrees.

At 1300 hours Moscow time on 8 June, the Salyut scientific station completed 21 orbits around the Earth with the cosmonauts on board. According to the data from the telemetric information and the cosmonaut's reports, the state of the onboard systems and the microclimatic parameters in the compartments of the Salyut scientific station were normal.

Cosmonauts Dobrovol'skiy, Volkov and Patsayev felt good and continued the planned studies.

Flight Control Center, 8 June 1971. The second working day of the crew of the Salyut orbital manned scientific station ended. The cosmonauts devoted this entire day to checking the systems and unpacking the scientific equipment of the Salyut station in order to prepare for research and experiments.

From 1500 hours Moscow time to one o'clock at night on 9 June the orbital station will be outside the zone of radio contact with the territory of the USSR. During this period the cosmonauts will take turns resting, doing physical exercises, and doing mutual medical monitoring and self-monitoring.

9 JUNE

Flight Control Center, 9 June 1971. The crew of the Salyut orbital scientific station began the third working day according to the program near one o'clock at night Moscow time on 9 June.

The cosmonauts are continuing to adjust the various scientific equipment of the orbital station and doing medical-biological experiments. The crew commander has reported that all of the cosmonauts feel good, and the work on the station is going according to plan.

The Flight Control Center confirms the stable radio communications with the Salyut station.

Flight Control Center, 9 June 1971. The third working day of Georgiy Dobrovol'skiy, Vladislav Volkov, and Viktor Patsayev ended at 1500 hours Moscow time. It was devoted to performing experiments and preparing the station for further work.

After the morning toilet and breakfast, the crew proceeded with the planned program. The canning of a number of systems on the Soyuz-11 spacecraft was completed. Further monitoring of the condition of the onboard systems and assemblies of the transport ship will be carried out according to the telemetric data.

The cosmonauts performed several medical-biological experiments. In order to stay in good physical condition in flight, they are using special weighted suits by means of which the Earth load on the human skeletal-muscular system is simulated. The cosmonauts have reported that the suits are convenient for work and do not create unfavorable sensations.

The gas composition of the station microatmosphere has been checked regularly. Further checking of the basic station systems, adjustment and tuning of the scientific apparatus and instruments continued.

During the course of the work according to the flight program, experiments were started to measure the radiation level and observe the micrometeoritic situation in outer space.

In the experiments performed today, a wide-angle viewer was tested. It is a new instrument designed for exact orientation on the sun and planets. In accordance with the flight program at 1006 hours a second correction to the Salyut station orbit was made after which the station went into an orbit with the parameters:

Maximum distance from the Earth's surface (apogee) 282 kilometers;

Minimum distance from the Earth's surface (perigee) 259 kilometers;

Time for one orbit around the Earth 89.7 minutes;

Inclination of orbit 51.6 degrees.

By 1500 hours Moscow time on 9 June, the Salyut scientific station with the cosmonauts on board had completed 38 orbits around the Earth.

According to telemetric data and the reports by the cosmonauts, normal conditions prevail in the compartments of the station. The condition of the onboard systems is good.

The specialists from the Flight Control Center have noted that the Salyut scientific station crew is working with good spirits, clearly and certainly. The Cosmonauts G. T. Dobrovol'skiy, V. N. Volkov and V. I. Patsayev feel great. The flight of the Salyut scientific station is continuing.

From a Verbatim Report of the Radio Conversations of the Crew with the Flight Control Center

9 June 1971, 0829 hours

Yantar'-1[1]. Yesterday I performed the orientation before the twist; the ship handles very well; everything went off well.

Yantar'-2 (comments on the programmed turn). I am monitoring the programmed turn. The engines are operating remarkably. We are looking out the port from the first station. Those flashes, there are flashes.

We are observing the spacecraft turns, the nozzles are working, everything is performing normally.

9 June 1971, 1000 hours. A correction is made to the orbit; an engine is operating.

Yantar'-2. The engine has been switched on; I am counting the time.

Zar'ya[2]. Roger.

Yantar'-2. Engine start smooth; now it is noticeable how the ship is going.

Zar'ya. Roger.

Yantar'-2. It's trembling a little now and then; the machine is trembling.

Yantar'-1. The engine operated 73 seconds and disconnected from the integrator.

Yantar'-3. Engine parameters normal.

Zar'ya. Roger, I understood you, Yantar'-1. The telemetry confirms: the engine operated 73 seconds.

9 June 1971, 1144 hours

Zar'ya. The answer to your question about the Pingvin [Penquin][3].

The metal plate must be above the knee. The height of the plate can be regulated by a hidden cord which is in the vicinity of the lower part of the knee. To eliminate the unpleasant sensation bend the plate in the shape of the leg. For tension on the shock absorbers pull the straps located at the position of the back pockets of ordinary pants in the fold of the Pingvin shell.

[1]The code names of the Salyut station crew are as follows: Yantar'-1 — G. T. Dobrovol'skiy, Yantar'-2 — V. N. Volkov, Yantar'-3 — V. I. Patsayev.

[2]Call name of the Flight Control Center.

[3]The suit for weightlessness conditions. It creates a dosed physical load.

Yantar'-2. Yantar'-1 feels great in his suit.

Zar'ya. Okay.

From the Notebook of V. I. Patsayev.

9 June 1971. In the flight part of the orbit the stars almost are invisible even in the port opposite the sun. Only Sirius and Vega are visible.

On the horizon at sundown the stars do not twinkle even to the edge of the Earth.

Note. 1. Make a protective cap for the toggle switch to the control arm.

2. The sealing device for the waste bags must be improved.

10 JUNE

Flight Control Center, 10 June 1971. Today at one o'clock at night, the fourth work day of the crew of the Salyut orbital scientific station began. After resting the cosmonauts performed physical exercises using special equipment.

A significant part of the program for the fourth work day was taken up with medical-biological experiments.

By the report of the station commander, the state of health of the cosmonauts is good, and the attitude is excellent.

Flight Control Center, 10 June 1971. The basic part of the program for the fourth work day of the crew of the Salyut orbital scientific station was devoted to medical-biological research. One of the experiments performed today was designed to obtain scientific information about the functional state of the cardiovascular system under conditions of weightlessness.

The studies were performed using a special multichannel amplifying-converting device with the application of functional tests. The recording of the physiological parameters at the time of the experiment was made by a telemetric channel.

In order to estimate the effect of the conditions of weightlessness on the variations in the human organism, an experiment was performed to determine the density of the bony tissues.

Microanalyzers were used to take blood from all of the crew members for subsequent laboratory tests on Earth.

In one of the communication sessions a television report was made from onboard the station in which the crew members told the television viewers about themselves and their comrades and also about the goals and missions of the flight.

The onboard systems and scientific equipment of the Salyut orbital scientific station are functioning normally. The Cosmonauts Dobrovol'skiy, Volkov and Patsayev feel good.

At 1440 hours Moscow time, the scientific station left the zone of radio communications with the territory of the Soviet Union.

The flight of the Salyut station continues.

From a Verbatim Report of the Radio Conversations of the Crew with the Flight Control Center

10 June 1971, 0051 hours

Zar'ya. Good morning.

Yantar'-1. Good morning. I report. Onboard everything is in order. Now Yantar'-2 has done his physical exercises on the track. Yantar'-3 is resting. During the period from 1600 hours to 1830 hours, fan No 7 buzzed; apparently something got into it. We could not find a way to get to it. We opened the panel... After 1830 hours the buzzing stopped. May we switch to the second fan?

Zar'ya. We read you. You may. During physical exercises perform the following experiment. Whoever is performing the physical exercises must switch on the track at some time and run on it, and the observer must observe the fluctuations of the cells through the port of the launch apparatus. It is necessary visually to estimate the period and amplitude of the oscillations.

10 June 1971, 0354 hours

Zar'ya. Yantar's, today we have medical inspection; therefore don't take off the belt, do you read me?

Yantar'-1. I shall connect periodically.

From the Journal of V. N. Volkov

10 June 1971. Excercises on the track and the expander.

Toilet. I brushed my teeth with real toothpaste.

Again something got into the fan. This time it was a voblaf packet.

The medical belt was removed. There was no irritation.

Viktor is sleeping in the transfer compartment. His hands stick out of the sleeping bag and hang miraculously in the air. Zhora is in his place (the left-hand chair of the first station). He put the new paste under the medical belt sensor.

I shaved, but only a little -- I decided to let my beard grow.

11 JUNE

Flight Control Center, 11 June 1971. At one o'clock at night Moscow time the Salyut manned orbital scientific station again entered the zone of radio communications with the territory of the Soviet Union. The crew Commander Dobrovol'skiy reported in the first communications session that the cosmonauts feel good and are continuing the flight program. All of the onboard systems and scientific apparatus are operating normally.

Flight Control Center, 11 June 1971. The orbital scientific station, Salyut, is successfully continuing its space flight. At 1400 hours Moscow time, it completed 863 orbits around the Earth, including 68 with crew.

During the fifth working day the cosmonauts took spectrographic measurements of individual sections of the Earth's surface within the territory of the Soviet Union in order to obtain the spectral characteristics of the various natural formations and water surface. Simultaneously the spectrometer was used to measure the optical characteristics of the atmosphere.

Experiments were started using the gamma telescope installed onboard the station. The purpose of these experiments includes study of the intensity, angular distribution and energy spectrum of the primary cosmic gamma radiation.

The Flight Engineer V. N. Volkov oriented distortion according to the experimental program. He put it in the automated stabilization mode, and crew Commander G. T. Dobrovol'skiy switched on the gamma telescope and monitored his work.

During execution of the program for the day, an experiment was performed to study the effect of the cosmic medium on the properties of special optical specimens investigated for purposes of developing transatmospheric astronomical telescopes.

According to the data obtained by means of the improved medical apparatus, the functional state of Dobrovol'skiy, Volkov and Patsayev is good.

At 1306 hours Moscow time the Salyut orbital scientific station left the zone of direct radio contact with the territory of the Soviet Union. After this the radio communications with the station crew were maintained via the scientific research ship Akademic Sergey Korolev which was in the Atlantic Ocean, and via the Molniya-1 communications satellite.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

11 June 1971, 1547 hours

Zarya. Yantari, the control group collective expresses its sincere appreciation for the work in the last day. We wish you a good rest and new strength on the new working day in a mood full of enthusiasm.

Yantar'-2. Thank you. It is nice to hear the appraisal. If we feel like today we shall proceed normally.

From V. N. Volkov's Journal

11 June 1971. The program of the day is very loaded: it is impossible to do this if we consider adaptation to the life conditions on an orbital station.

The sleeping bags must be made more convenient in order not to spend so much time opening and closing them. The food products are the same as always: few juices.

12 JUNE

Flight Control Center. 12 June 1971. Today at 0040 hours, the manned orbital scientific station Salyut again entered the zone of radio contact with the territory of the Soviet Union. The Flight Control Center is maintaining stable radio contact with the station.

Cosmonauts Dobrovol'skiy, Volkov and Patsayev feel good. The onboard systems of the station and the scientific apparatus are operating normally.

Flight Control Center. 12 June 1971. In the course of the next working day the crew of the Salyut scientific station carried out the program of medical-biological experiments. By using a special dosimetric apparatus the cosmonauts performed experiments in order to obtain data on the radiation safety of space flights and create an effective dosimetric control system. Here, the magnitudes and the dynamics of the increase in radiation doses by various components of cosmic radiation were determined.

Studies were made of the state of the cardiovascular system and functional tests were made of the external respiration, gas metabolism and energy expenditures. The cosmonauts investigated the light and contrast sensitivity of the visual analyzer under the conditions of variable brightnesses.

During the course of working on the program of the day, the cosmonauts photographed various atmospheric formations using a camera with different focal lengths.

In the radiocommunications sessions, Cosmonauts Dobrovol'skiy, Volkov and Patsayev gave television reports in which they told the story of the structure of the Salyut station started in preceding television appearances. At 1430 hours Moscow time, the Salyut station left the zone of radio contact with the territory of the Soviet Union.

From V. N. Volkov's Journal

12 June 1971. We got up, we drank water from the new barrel. We drank all of the first one. Viktor set up the vacuum and I floated about the cabinet cleaning it. Zhora was in the chair as assigned to try to write something in the log.

Viktor made a place to sleep in the hatch between the descent apparatus and the orbital compartment. Soon communications with the Earth will be re-established, and meanwhile according to orders, gymnastics.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

12 June 1971. 0041 hours

Yantar'-3. Now we have a complaint with respect to the medical sensors. It is inconvenient to wear them all the time. I have not taken them off for three days; there are dents in my body from the sensors. Let us talk a little, Zarya: you can have communications sessions with us during which the telemetry will be recorded. We shall put them on for that. The rest of the time we shall take them off.

Zarya. Understood. Carry out your proposal.

12 June 1971. 0212 hours

Yantar'-1. Now with regard to psychology. It appears to me that the psychologists are worried about nothing. The only thing is that we have to do three times as much physical culture. And more frequently. First, people will look at each other... It is necessary to force oneself to do physical exercise. It is necessary to increase the exercise time approximately to 30 minutes. All of the new operations should be planned so that they are done twice or three times. A minimum of two times. Things would go better then.

Zarya. With regard to physical culture. You can do it three times 30 to 40 minutes each.

Yantar'-1. Okay. Now about the work. All of the new operations will also be planned for three. The work with the Polinoma [Polynomial] sensors[1] and elimination of errors can in general only be done in threes. This will be interesting ...

Zarya. I understand.

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[1] A set of medical monitoring instruments.

Yantar'-1. And, in addition, it will be easier to repeat the operation.

12 June 1971. 0344 hours

Zarya. Yantar'-2, make the movie, observe the most noticeable atmospheric phenomena and transmit to us: what and how.

Yantar'-2. Now we see a forest fire below.

Zarya. Roger. Note another communique: report insofar as possible on the state of the port. Is observation of the stars possible?

Yantar'-2. No, in the daytime you can not see stars. They can be seen only before sunset or before sunrise.

Zarya. Roger.

Yantar'-2. The ports are clean.

Zarya. Are there differences in the flares at night and day during operation of the orientation engines?

Yantar'-2. There are differences.

Zarya. What differences, can you transmit?

Yantar'-2. At night the flares are brighter.

Zarya. Is it possible to recognize stars in the twist?

Yantar'-2. It is possible to recognize the stars during a twist. Zarya, still through the ports. They are in an excellent condition, but some of them are a little coated with moisture. The stars on the day side are not visible. I have made several observations, even Jupiter, which is now in the constellation of Scorpio, is also invisible.

12 June 1971. 0511 hours

Yantar'-1. The remarks with respect to the stars. We have again looked: the stars are not visible in the daytime. Just before going into the shadow, Jupiter appears first, then the stars begin to show up.

12 June 1971. 0811 hours

Zarya. Yantar'-2, another question for you. Have you succeeded in doing the experiments and receiving information?

Yantar'-2. Understand, it is still difficult with time. Now, for example, we are preparing the Polinom. We have spent one hour and twenty minutes on this.

Zarya. Understood.

Yantar'-2. The difficulty is that the man is not tied in the chair... Everything flies away: you get one thing, and another flies away.

From the Notebook of V. I. Patsayev

At night the stars and the Earth are well visible. The clouds and the cities at night (the lights on the ground) are visible.

The edge of the Earth is guessed by the absence of stars.

At sunrise and sunset, the upper clouds against the background of the lower clouds are reflected by long fiery trails.

Are the stars visible in the daytime?

This depends on the sun altitude. At an angle of less than 15 degrees the large stars and planets are visible.

Television Interview of V. N. Volkov. 12 June 1971

Zarya-25[1]. Flight Engineer V. N. Volkov made contact. We know that the orbital station for you is temporarily home and laboratory and even gymnasium. We should like to hear from you a more detailed account and have the first television appearance from the Salyut. Now a portable television camera has been collected from the ground. How do you read us?

Yantar'-2. I understood you excellently. It pleases me a great deal to begin the first television interview and the first television visit on the Salyut orbital station.

The orbital station comprises two compartments: orbital, which we now see on the screen, and the Soyuz ship which has docked with it. I shall show it to you; there you see the Soyuz spacecraft from afar docked with the orbital station. You can have an idea of the dimensions which this orbital station has.

Here comes the research engineer floating from his compartment.

Zarya-25. We see him excellently.

Yantar'-2. Now I shall show you another part of our orbital station.

We have the sports complex, of course, not so large as the arena in Luzhnikiy. This is the medical chair, this is the belt on which you will run. Indeed, the camera and the operating equipment; the work space of the research engineer, his on-board log and control panel. This is why the centralized control panel from which the orbital station and the spacecraft are controlled simultaneously.

[1]Code name of the central television commentator.

In general, the spacecraft is a very large laboratory permitting the solution of an enormous set of scientific and engineering problems for the national economy, problems which permit expansion of our knowledge of the space about the Earth.

Here, on the screens you see photographs of S. P. Korolev, Yu. A. Gagarin and a portrait of V. I. Lenin. They are always with us. Now I shall show you the docking unit more closely. Here is the docking location. If there are questions, please. Do you see the docking point?

Zarya-25. We see excellently.

Yantar'-2. This is the orbital compartment; this is the changing compartment. This is the sleeping area; we rest here.

Zarya-25. We see excellently. There is another second of time. Can Yantar'-1 give an estimate of the past week?

Yantar'-2. Please.

Yantar'-1. Zarya, I hear you excellently. If we evaluate briefly: all systems of the ship are operating excellently, the crew feels good. They are ready to continue to work by the program. The assignment which has been trusted to us will be carried out with high-quality, applying all our forces.

13 JUNE

Flight Control Center. 13 June 1971. The Salyut manned scientific station, completing its 93-rd orbit around the Earth with the crew onboard entered into the zone of radio contact with the territory of the Soviet Union at 0034 hours Moscow time.

According to the reports of the cosmonauts and the data from analyzing the telemetric information, all of the onboard systems and the scientific apparatus of the station are operating normally. The Cosmonauts Dobrovol'skiy, Volkov and Patsayev feel good.

At 0806 hours during the next radiocommunication session, the cosmonauts transmitted a radiogram to the Soviet people in connection with the national election day.

Flight Control Center. 13 June 1971. The first manned orbital station, Salyut, completed 100 orbits around the Earth at 1300 hours. The Cosmonauts Georgiy Dobrovol'skiy, Vladislav Volkov and Viktor Patsayev are continuing successfully to execute the program of scientific and technical experiments, maintaining high fitness for work.

The procedure of work and rest of the crew members has been worked out considering the round-the-clock performance of scientific research. Thus, the next work day for the Flight Engineer Volkov began yesterday at 2130 hours; for the station Commander Dobrovol'skiy it began at 0150 hours on the night of 13 June, and for Test Engineer Patsayev, at 0600 hours.

During the course of these days, the cosmonauts observed and photographed the cloud cover of the Earth and the segments of the Earth's surface characteristic from the geological point of view. The characteristics of the primary cosmic radiation were measured.

Onboard the Salyut station experiments are continuing to study the effect of the conditions of weightlessness on the development of high-order plants. For this purpose, flax, cabbage and onions are being grown by the hydroponic method. Observations are constantly made of the plants which are regularly fed a nutrient solution.

The work onboard the station alternates with the execution of a complex of various physical exercises. One of the means of maintaining the required fitness for work by the cosmonauts is exercises performed with the application of special devices and accessories. In particular, a moving track is used which permits maintenance of the skills of walking and muscle strength under conditions of weightlessness.

At 1255 hours the Salyut station left the zone of radio visibility from the territory of the Soviet Union. In the nearest orbits, communications with the station are maintained using the scientific research ship Akademik Sergey Korolev located in the North Atlantic and the Molniya-1 communications satellite.

<u>From the Journal of V. N. Volkov</u>

<u>13 June 1971. Eighth Day of Flight</u>. We crossed the Equator. The 387-th orbit began. The boys are asleep. Zhora is in the transfer compartment buried in the instruments. Viktor is not to be seen. He is in the wash area in the orbital compartment on a bunk. I have already done my physical exercises and had breakfast (the first breakfast was canned bacon, blackberry juice, prunes with nuts, and candied fruits), and I drank some water.

We are still outside the visibility of our stations, but I am still in communication, and every now and then I receive something! After the communications session I shall perform a medical experiment.

I have observed the stellar sky. In the upper light layer of the night horizon the stars of Beta Ursa Major are clearly to be seen. With the coming of sunrise when the antennas begin to be lit up, the stars disappear, but not all of them.

In the morning we vacuumed the compartment. It appears that the water has all been used up in the second tank. This is the second since the beginning of the flight.

From the Journal of V. N. Volkov (continuation)

I have just finished breakfast. I have done my physical exercises. I did 100 kneebends. Two green stalks about 2 cm high have crawled out of the Oasis[1]. The boys are still asleep. It is time to wake up Zhora. He is supposed to get up at 0130 hours, and it is already 0200 hours. The antenna is brightly lighted in the port. This means the next sunrise has come. Ground control has asked us to wear the medical sensors. I have put on the belt.

It is an interesting picture: the Earth is black and the sky also, but the antenna of the solar cell is a bright white.

The communications session has started. In my earphones I can hear the song from the movie "Fighter Planes: "My comrade flies off into the distance" ...

"Zhora has awakened!" — "Do you have anything good to say?" "Greetings," I say jokingly.

"I have measured my hand strength on the dynamometer -- 35/32. How is that! That is very good.

"My pulse is 52."

From the Daily Log of V. I. Patsayev

13 June 1971. In the port opposite the sun frost is visible on the inside surface of the outer glass.

Note: 1. The bag with the tools has long straps (closing it). It would be better to have cleats.

2. The plug for the vacuum cleaner is located low -- it is inconvenient to operate and dark.

14 JUNE

Flight Control Center, 14 June 1971. At 2253 hours Moscow time on 13 June the manned orbital scientific station Salyut on the 108-th orbit around the Earth entered the zone of radio contact with the territory of the Soviet Union.

The cosmonauts feel good; they are successfully continuing their flight program. All of the station systems are functioning normally.

At 0900 hours on the morning of 14 June the Salyut station was in orbit with the following parameters:

Maximum distance from the Earth's surface (in apogee) 277 kilometers;

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[1] The set-up for growing high-altitude plants onboard the Salyut station.

Minimum distance from the Earth's surface (in perigee), 255 kilometers;

Period of one turn around the Earth -- 89.6 minutes;

Inclination of orbit -- 51.6 degrees.

Stable radiocommunications are being maintained with the Salyut station. The metering command complex of the Soviet Union is performing systematic trajectory measurements and receiving broad scientific information from the station.

Flight Control Center, 14 June 1971. The crew of the Salyut scientific station is continuing the planned program of scientific research and experimentation.

During the course of the working day experiments were performed with respect to developing an autonomous navigation system. The Flight Engineer Vladislav Volkov and Test Engineer Viktor Patsayev have performed navigational measurements by the results of which Viktor Patsayev has determined the orbital parameters of the station using the onboard digital computer.

In order to obtain the spectral characteristics of different natural formations the cosmonauts have performed spectrographic measurements of the individual sections of the Earth's surface.

The cosmonauts have observed the cloud cover of the Earth and traced the formation of typhoons and cyclones. They have photographed the Earth's surface. The joint meteorological experiment has been performed again with the Meteor satellite.

In one of the communication sessions the cosmonauts have done television reporting.

In order to determine the accommodation capacity of the eyes during prolonged optical observations in space flight using a special instrument, a study was made of the accommodation and convergence of the eyes of the cosmonauts. The experiment was performed for 30 minutes while the station was on the light side of the Earth.

By the reports of the cosmonauts and the data from telemetric information, all of the onboard systems of the station are operating normally; the given conditions are being maintained in the compartments.

By the report of the Commander of the Salyut scientific station, Georgiy Dobrovol'skiy, the members of the crew are feeling good.

At 1230 hours, the Salyut scientific station left the zone of radiocommunications with the territory of the Soviet Union. Communications with the station crew are being maintained by means of the scientific research ship Akademik Sergey Korolev and via the Molniya-1 communications satellite.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

14 June 1971. 0312 hours

Yantar'-2. Give us more Mayak's[1]. We are very bored without them. They can be heard very well over South America. We can not hear them anywhere else.

14 June 1971. 0756 hours

Yantar'-3. Have you seen us?

Zarya. We have seen you.

Yantar'-3. I now give you our leader -- here he is in all his beauty.

From the Daily Log of V. I. Patsayev

14 June 1971. We have worked in the turning mode on the sun. The station sometimes quivers -- two or three weak jolts. Obviously, this is connected with the overflow of liquids.

Note. All the control panels for the scientific equipment must be covered with safety covers made of organic glass.

Luminescent particles frequently accompany the station and fly in different directions. These are dust particles or fine crumbs.

15 JUNE

Flight Control Center. 15 June 1971. The Salyut manned orbital scientific station completed 134 orbits around the Earth by 1500 hours Moscow time.

The next working day of the crew began yesterday at 2245 hours when the Salyut station entered the zone of radio contact with the territory of the Soviet Union. Flight Engineer Volkov was the first on space watch. The station Commander Dobrovol'skiy went to work on 15 June at 0330 hours; Test Engineer Patsayev's work day began somewhat later.

During the course of the day the cosmonauts performed individual experiments started earlier, performing them in new operating modes of the equipment.

The cosmonauts took a spectral recording of the characteristic formations of the Earth's surface in the coastal zones of the Caspian Sea in order to use the data obtained in agriculture, land improvement, geodesy and cartography. Aerial photographs were taken simultaneously of these regions from specially equipped expeditionary aircraft from the Leningrad State University and the USSR Academy of Sciences.

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[1] Transmissions of the Mayak radio programs.

From onboard the Salyut station the crew continued to take photographs of the cloud cover over parts of Povolzh'ye. The simultaneous television pictures of the same cloud formations were taken by the Meteor satellite. The purpose of this experiment is to study the fine structure of the cloud systems and to process the method of decoding the television pictures received from the Meteor satellite.

In order to obtain data on radiation safety in spacecraft and to create an effective system of dosimetric control, the measurements of the surface and deep radiation doses and determination of the relative biological efficiency of cosmic radiation were continued.

For separate recording of protons, neutrons and gamma-quanta against a background of cosmic radiation the scientific measuring equipment was switched on more than once.

When performing the medical-biological experimentation program, complex studies of the cardiovascular system were continued. In the television communications sessions the cosmonauts told about the experiments and demonstrated the scientific equipment.

By the report of the station Commander Dobrovol'skiy and the telemetric data, the cosmonauts are fine.

At 1236 hours, the Salyut orbital scientific station left the zone of radio contact with the territory of the Soviet Union.

Television Interview of V. N. Volkov

15 June 1971.

Zarya-25. How do you read me?

Yantar'-2. Yantar'-2 in communication.

Zarya-25. Reception is excellent. We would like you to tell about the experiment on the cardiovascular system.

Yantar'-2. One of the most important problems which will be stated for us on this flight is performing medical experiments. The accumulated information will permit our scientists to draw correct conclusions regarding the possibility of a man staying for a long time in space.

Today I would like to familiarize you with one such experiment... I shall demonstrate this to you more closely.

Zarya-25. Please. Incidentally, Vladislav Nikolayevich, how are you feeling? How is the entire crew?

Yantar'-2. The crew feels excellent which has been promoted to no small degree by our training on the ground.

Now, dear comrades, you will see Viktor Patsayev, who is preparing to do the next medical study. Ship Commander Georgiy Dobrovol'skiy will help him.

The experiment is being performed using the equipment which you saw on your screen. Now Viktor Patsayev is demonstrating the apparatus on which the physiological parameters will be recorded...

From the Daily Log of V. I. Patsayev

15 June 1971. With the sun low (immediately after sunrise or before sunset), the Earth is in a haze (there is a shroud above the surface although there are no visible clouds). Obviously some layers of the atmosphere have been illuminated from the side.

Sometimes enormous cloud fields of mosaic structure stretching no less than 1000 km, for example, 17.40 above 50 degrees south latitude and 350 degrees east longitude in the ocean between South America and South Africa occur. The clouds hovering above the water look like foam floating on the water.

The color of the oceans is a delicate blue. The waves are visible almost always in the port opposite the sun when the sun is high. The wake of ships is visible.

Inversion trails are visible from aircraft.

16 JUNE

Flight Control Center. 16 June 1971. By 1200 hours Moscow time the Salyut manned orbital station completed the 148-th turn around the Earth.

During the flight days which have passed, the station crew has performed technical experiments, the purpose of which was to develop new means of manual and automated control of the motion of spacecraft. During the course of these experiments, the possibility of manual control by means of a wide-angle optical viewer and a high-speed optical vertical plotter was checked.

Crew Commander Georgiy Dobrovol'skiy and Flight Engineer Vladislav Volkov checked the accuracy characteristics of the new ion-orientation equipment with inclusion of it in the in the automated motion control circuit. Here, the accuracy was controlled by the optical vertical plotter, the visual astro-orientation unit and other instruments of the motion control system.

The mass composition of the upper atmosphere was investigated simultaneously by means of radio-frequency mass spectrometers. During operation of the control engines, photometric measurements were made of the light effects occurring during them. The Test Engineer Viktor Patsayev continued navigational measurements and the processing of scientific results on the onboard computer.

The crew members all feel good. The pulse rate of Dobrovol'skiy is 78, Volkov's pulse rate is 58, and Patsayev's is 77. The magnitudes of the arterial pressure are close to the initial and are 135 over 75, 118 over 55 and 135 over 85 mm Hg respectively.

The coordination-computation center is continuing to process the broad scientific information coming from the station.

17 JUNE

Flight Control Center. 17 June 1971. At 2230 hours Moscow time on 16 June the manned orbital scientific station Salyut, completing up to that time 155 turns around the Earth, again entered the zone of radio contact with the territory of the Soviet Union.

During the working day of 16 June the cosmonauts continued to perform scientific-technical experiments.

Test Engineer Viktor Patsayev began to perform a new technical experiment. This experiment consisted in studying the phenomenon of high-frequency electron resonance on the transmitting radio antennas under the conditions of space flight and research in the field of high-temperature plasma.

The phenomenon of high-frequency electron resonance can essentially worsen the operating conditions of the transmitting antennas, and it is up to now little-investigated. In the experiment the conditions of the occurrence of such processes were determined, and the values of the attenuation of the radio signal caused by this phenomenon were measured. The distortions of the spatial characteristics of the radiation of antennas of various types were studied also. During the experiment, in addition, some measures were evaluated for suppressing the process of high-frequency electron resonance.

The measurements of the spatial distribution of charged particles taken simultaneously and the recordings of the ions and electrons in orbit close to circular were of independent interest. The laws discovered in this case permit us to obtain new data for the development of high-accuracy ion-orientation sensors.

According to the flight program, 17 June was a rest day for the crew. The cosmonauts did physical exercises and mutual medical tests. They also rested.

The Cosmonauts Dobrovol'skiy, Volkov and Patsayev felt good. The crew of the Salyut orbital scientific station is continuing to perform the intended flight program.

From the Verbatim Copy of Radio Conversations by the Crew with the Flight Control Center

17 June 1971. 0426 hours

Zarya. A functional test was run on the equipment on the 955-th orbit.

Yantar'-1. How is the composition of the atmosphere?

Zarya. The atmospheric composition in our compartment is normal.

Yantar'-1. Check the oxygen.

Zarya. Our oxygen is normal. The ground control is seeing to this.

17 June 1971. 0731 hours

Zarya. Yantar'-2. Do you remember that on the 957-th orbit Yantar'-3 was dizzy.

Yantar'-2. I was just going to wake them, but it is a pity the boys were tired.

Zarya. It is not necessary, not necessary now. Let them rest.

17 June 1971. 1156 hours

Zarya. There is one question. How many times and under what conditions with respect to time and resolution has the vacuum tank been used by each of us? The answer can be ready tomorrow if you do not have it now.

Yantar'-1. I read you. The vacuum tank is a good thing. I tried it out, and reached a rarefaction of 700 mm, and everything was excellent. The g-loads are not the same as on the Earth. They are much less, and therefore it is possible safely to provide a large vacuum.

18 JUNE

Flight Control Center. 18 June 1971. At 1430 hours Moscow time, the Salyut manned orbital station completed the 182-nd orbit around the Earth.

During the course of the program for the working day, experiments were started using the orbital astrophysics observatory Orion installed onboard the station. In these experiments the entire composition of the observatory equipment will be tested under the conditions of space flight. Its fitness will be checked after prolonged stay in outer space, and the spectral characteristics of the individual stars in the short-wave radiation range will be obtained which are unavailable for study from the ground.

After performing the complex tests on the observatory systems, in accordance with the program, Viktor Patsayev recognized the star selected for study. He aimed the viewer on it after which a special system did an automatic lockon orientation and tracking of the star during the given time period. A spectrographic measurement was taken of the star.

The first experiment performed with the Orion observatory confirmed the correctness of the basic principles of its development, the basic principles of the creation of orbital astrophysics observatories operating under conditions of outer space and controlled by the cosmonaut inside an orbital station.

The cosmonauts transmitted a television interview in which they talked about the observations made onboard the station and the studies of the Earth's surface in the interests of the national economy.

The crew members of the Salyut orbital station feel good. Cosmonauts Dobrovol'skiy, Volkov and Patsayev are continuing to carry out the flight program.

From the Verbatim Report of the Radio Conversations of the Crew with the Flight Control Center

18 June 1971. 0724 hours

Yantar'-3. You hear well, right? At the fixed time, an experiment was run with Orion[1], the second mode, by the second star, map No 3. Work was started at 0634 hours. The program was switched on at 0645 hours. The exposures 10, 30, 90 and 270 took place normally. Now I shall more precisely determine the rewind time, and I shall report later. All of the lights -- green, orange and white -- have lost their color. For the rest, everything is normal. The report is finished.

Zarya. The third track continues to operate. The control group considers its operation normal.

Yantar'-1. Yes, it is also satisfactory.

Zarya. Yantar'-3, a reminder for you. Before beginning the second half of the experiment do not forget to check that the fifth control panel of the scientific apparatus is switched on.

Yantar'-3. I shall not forget. I have been ready for a long time: I shall carefully wipe the port and the glass of the viewer with a chamois. It was adjusted earlier. Everything is normal.

Zarya. Excellent, excellent. According to the preliminary data, everything is satisfactory with the first part of the experiment.

Yantar'-3. Indeed, it has turned out well. We are also satisfied, and the object has become good, and the automation has kept everything good.

18 June 1971. 1321 hours

Yantar'-3. I shall report the situation with respect to Orion. Work has been done on the third star. The work has gone successfully with the exception of the fact that the last delay of 810 seconds as a result of sunrise could not be done, and it was necessary to limit ourselves to holding 720

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[1] Astrophysics observatory for study of spectral stars.

seconds. For the rest everything is normal. The time shortage comes from the fact that the antenna has been illuminated for a long time...

Zarya. I understand, Yantar'-3, thank you for the information.

Yantar'-3. You're welcome.

Zarya. Yantar'-3, inasmuch as we shall not be here tomorrow, the group sends you birthday greetings today.

Yantar'-3. Thank you, thank you.

Zarya. We wish you well, congratulations there for tomorrow. We congratulate you from the bottoms of our hearts.

Yantar'-3. Thank you.

Zarya. Yes, yes, you get a whole tube of juice tomorrow.

Yantar'-3. Even the glass, right.

Zarya. Well, Yantar'-3, you'll find out about that. Until tomorrow.

18 June 1971. 2219 hours

Yantar'-2. I just woke up, I slept about seven hours. I slept well. I feel good. The rest of the crew members are resting now.

Zarya. Where are the rest sleeping? In the work compartment?

Yantar'-2. Yes, again on the ceiling, near the filters. Their legs are stretched out on both sides. They are asleep.

19 JUNE

Flight Control Center, 19 June 1971. By 1420 hours Moscow time, the Salyut manned orbital station completed 198 orbits around the Earth.

The program for the next working day of the station crew included execution of scientific and medical experiments and the development of individual onboard systems.

Cosmonauts Volkov and Patsayev have performed optical research on the Earth's atmosphere by the method of spectrographic metering of the day and twilight horizon. In the experiment, the color range of the atmospheric halo and the day horizon and its dependence on the distribution of the aerosol particles and other optically active components in the atmosphere was determined.

By using the solar orientation device, the cosmonauts checked the accuracy of the gyroscopic instruments during the process of prolonged flight of the station oriented on the sun. According to the medical experimentation program, the studies of the cardiovascular system with the application of functional loads were continued. The visual functions insuring spatial perception and color perception were studied, and the measurements of the density of the bone tissue were taken.

As usual, the stressed work alternated with the execution of various physical exercises and rest.

All members of the crew feel good. The onboard systems and the scientific apparatus are functioning normally. According to the telemetric data, the temperature in the operating compartment of the station is + 22°Celsius, and the pressure is 880 mm Hg. The flight of the Salyut orbital scientific station is continuing.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

19 June 1971. 0713 hours

Zarya. We all congratulate Viktor Ivanovich on his birthday. We wish him successful work.

Yantar'-3. Thank you.

Yantar'-1. We wanted to arrange a day of rest for him, but he has a great deal of work to do.

Zarya. Everyone congratulates him and thinks that the commander will organize a banquet for him.

Yantar'-1. We have tried to arrange a day of physical culture for him and give him some rest, but he has a great deal of technical work to do.

Yantar'-1. I report: the photographs have been taken of the twilight horizon. The appearance of the sun, a small piece, was visible, less than half. We have taken photographs of this.

19 June 1971. 1019 hours

Zarya. Yantar'-3, come in please.

Yantar'-3. Yantar'-3.

Zarya. Yantar'-3, we again congratulate you on your birthday and wish you a successful flight assignment and much happiness in life. All of your family transmits their warmest best wishes.

Yantar'-3. Thank you for your greetings, however far away you are from us, we constantly feel your support.

19 June 1971. 2158 hours

Zarya. How are the plants? How are they for moisture?

Yantar'-2. Well, the plants -- they are our love. They grow and grow. Viktor is seeing after them and changing the regime. They are growing by themselves. There is moisture inside. It is impossible to water them here. Everything flies away.

Zarya. Do you hear shortwave?

Yantar'-2. Shortwave is quite clear as we approach the equator over South America. I will switch on our shortwave directly there to make you happy.

Zarya. It is too bad that we can not stop and listen.

Yantar'-2. Yes, that is too bad. As soon as you leave these parts everything drops, and it is hard to hear. There is some kind of interference. When music plays it is more or less audible, and when there is talking, it is inaudible.

From the Daily Log of G. T. Dobrovol'skiy

19 June 1971. Viktor's birthday. A congratulatory note from Viktor's wife with the following words: "Mother arrived, she feels good"... Viktor was very touched.

From the Journal of V. N. Volkov

19 June 1971. Today is Viktor's birthday. The celebration table was laid. The delicacy was onions. He was congratulated by Zarya, and an interview was requested from the ground.

2130 hours. On duty. Probably I shall be the first to see the 1000-th orbit on the globus counter. This historical event fell within my duty hours. It is simply incomprehensible.

We are sleeping in a new place. The places are like in a coupe. I have slept well -- about 8 hours -- for two days. Tomorrow we shall expect a "good morning" transmission. This has to be done by order.

20 JUNE

Flight Control Center, 20 June 1971. At 0214 hours Moscow time, the Salyut scientific orbital station completed the 1000-th orbit around the Earth. Of these 206 orbits were with the crew on board.

In accordance with the program for 20 June, Cosmonauts Georgiy Dobrovol'skiy Vladislav Volkov and Viktor Patsayev are resting. In the communications sessions the crew of the scientific station held radio and television interviews telling about the structure of the orbital station and the operation of the scientific apparatus.

The cosmonauts also reported the results of their observations during the past day of the Earth's surface and the various meteorological phenomena. Thus, flying at 1458 hours on 19 June over the northwestern coast of Africa, the cosmonauts saw a dust storm.

According to the reports of the cosmonauts and the telemetric monitoring data, the crew felt good, the onboard systems and scientific apparatus of the station were operating normally. The flight of the manned orbital scientific station Salyut is continuing successfully.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

20 June 1971. 0059 hours

Yantar'-2. We are entering into the 1000-th orbit as a working orbit and although today is a rest day we have decided to devote it to further observations of our planet and photography of the Earth's cloud cover, oceans and continents for geology and the solution of other problems of the national economy. In general, we shall do the same work as we usually do on working orbits. We shall try to use every free moment to send as much data as possible to the Earth.

Zarya. We transmit our warmest greetings to you. Many congratulations.

Yantar'-2. Somewhere around 0400 hours when Viktor wakes up, we shall have physical culture and do what I said: we shall photograph and observe the Earth.

Zarya. If you have any data on hand, then tell us what you have done for the day with respect to medicine...

Yantar'-2. In practice we have done all of the experiments which the doctors need.

Zarya. Good, thank you, bright fellow.

Yantar'-2. I am keeping a careful account of the food and water consumption. To those who were interested I report: I am writing down everything. The data are ready on the system operations. We are writing that now. We are sharing on the craft; each of us has a number of problems. This is so we do everything as stipulated.

We are now flying over Africa, Saudi Arabia and Northwest Africa. There are many red fires below. There is a very bright planet in the constellation Capricorn.

Television Interview with G. T. Dobrovol'skiy. 20 June 1971

Zarya-25. Yantar'-1, you are the first commander of the crew of the Salyut manned orbital station. What are your impressions of this station?

Yantar'-1. I am enormously impressed. The fact is that I am in space for the first time and I was very happy to get the orbital station directly. This station comprises two ships: the transport ship which came to the orbital station and the station itself. In general, this is a complex. It permits the performance of many operations of a scientific nature. The designers, engineers and the golden hands of the industrial workers have all done what they could so the crew can rest as well as possible.

Zarya-25. According to your story we have understood that you have control of both the Soyuz spacecraft and the Salyut station, that is, the station docked with the Soyuz spacecraft. Obviously the characteristics of these objects are different. Is this apparent in any way in the space navigation techniques and equipment?

Yantar'-1. I can say that the skills which were acquired when preparing for the flight were justified. There are no difficulties. It is very easy to control the transport spacecraft and the orbital station as a whole. The spacecraft is highly responsive and easily manageable... In general, this is what each of us could dream about upon being sent into space.

Zarya-25. Understood. Yantar'-1, what peculiarities have you come up against in your work as commander of the orbital station?

Yantar'-1. The fact is that the most interesting work for us began immediately -- docking. We were very interested in how to do this best. And by how it took place apparently this was successful.

The second peculiarity, I would say, was the following: the station is very large, and there is a large field of activity for working here. It is necessary that all members of the crew clearly understand their duties. This is complicated. There was some roughness at the beginning, but after transfer to our orbital station, we have begun to work at full strength and everything has fallen into place.

Zarya-25. Thank you very much, Yantar'.

From the Verbatim Conversation of the Crew with the Flight Control Center

20 June 1971. 0357 hours

Zarya. Yantar'-3, for the first time all of our work with respect to Orion is satisfactory. Tomorrow working with Orion is also planned. Two sessions have been held using Orion on one or two stars?

Yantar'-1. Two stars.

20 June 1971. 0530 hours

Yantar'-1. Yesterday at 145800 hours on the northwest coast of Africa, 344 longitude, 17 latitude a dust storm was observed.

20 June 1971. 0836 hours

Zarya. I have a request. Water the plants twice a day -- at the beginning and at the end.

Yantar'-3. All right, the instructions say once a day.

Zarya. I know, I know... however they must be watered twice a day. Also report the general condition of the plants and the presence of the first real leave. Report on following days. Understood?

Yantar'-3. All right. Everything is clear.

21 JUNE

Flight Control Center, 21 June 1971. The third week of the scientific watch onboard the Salyut orbital station has started. After a day of rest the crew began its research.

Today work has continued with the Orion orbital astrophysics laboratory onboard the station. On the next orbit after the necessary operations have been performed with respect to general orientation of the station, "lock on" was carried out using a viewing system on one of the stars of the constellation Ophiuchus. The automated devices and tracking system of Orion have operated well.

On the next orbit an experiment was performed to expand the operating program of the astrophysics observatory. Test Engineer V. Patsayev controlled the operation of the two stellar telescopes of the observatory from the control panel simultaneously. One of the telescopes was located on the outside of the station hull, and the other, inside it. Both telescopes were directed at the same star Alpha Lyrae. Simultaneous operation of the two telescopes has the purpose of obtaining spectrograms of the ultraviolet radiation of the star in two different bands of the spectrum. By the readings of the control sensors and by V. Patsayev's report, the experiment with respect to joint operation of the two telescopes went successfully. Its realization was greatly promoted by the exact and smooth work of station Commander G. Dobrovol'skiy and Flight Engineer V. Volkov with respect to orienting the station on the given stars.

During the course of executing the program for the day, studies of the primary space gamma radiation were continued, the intensity of the electron background on the level of the station's orbit was recorded and the charged spectrum of the cosmic radiation nuclei was recorded.

The cosmonauts did the next medical research cycle. All the station systems are functioning normally. The cosmonauts feel good.

The flight of the Salyut scientific station is continuing in accordance with the planned program.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

21 June 1971. 1421 hours

Yantar'-3. Take a short radiogram.

"Leningrad. To the participants of the All-Union Congress of Meteorologists.

"Your anniversary meeting must reveal many secrets of nature. You can work quietly. And we shall see after the weather.

"Crew of the Salyut station. Dobrovol'skiy, Volkov, Patsayev."

From the Daily Log of V. I. Patsayev

The moon looks just like from the Earth.

Sometimes in the port opposite the sun it is possible to see an irridescent round spot (a circular rainbow similar to a halo).

By the shadows from the clouds it is possible to determine the cloud boundaries. The cumulus clouds run in regular rows, and the cloud strips on the night side are visible against the moon and without it.

22 JUNE

Flight Control Center, 22 June 1971. By 1200 hours Moscow time, the manned orbital scientific station Salyut completed the 245-th turn around the Earth.

Upon completing the program for the 16-day space flight, the Commander of the orbital station Georgiy Dobrovol'skiy continued to study the physical properties of the Earth's atmosphere using the manual spectrograph. In this experiment the cosmonaut performed spectrophotometric measurements of the twilight horizon of the Earth during sunrise and sunset. The measurements were started directly before the appearance of the edge of the solar disk and ended at the time of its complete emergence from behind the horizon. Similar measurements, but in the opposite sequence were also taken by Dobrovol'skiy as the sun set behind the horizon.

The studies of the light gamma of the space dawn performed onboard the Salyut station permit us to obtain exact data on the distribution of the optically active components of the Earth's atmosphere determining the distribution of the solar radiation in the atmosphere. In addition, the Test Engineer Viktor Patsayev performed an experiment during past days with respect to studying the polarization of solar light reflected from the Earth's surface.

In the television interviews the cosmonauts told about the biological experiments connected with the effect of weightlessness on the growth and development of the high-altitude plants.

The station crew also continued to observe the development of clouds over the Earth's surface, the movement of cyclones and other meteorological phenomena. In particular, the cosmonauts detected and performed a photographic survey of a cyclone in the vicintiy of the Hawaiian Islands. After several hours, the development of the cyclone was observed near the shores of Australia.

According to the data of the telemetric information, the temperature, pressure and gas composition of the atmosphere on the station are maintained within the given limits. The cosmonauts feel good.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

22 June 1971. 0201 hours

Yantar'-1. At a longitude of 168 degrees and a latitude of 30 degrees a large cyclone was detected and photographed.

22 June 1971. 0641 hours

Yantar'-2. Zarya, I am reporting. At 0636 hours at a longitude of 125 degrees, we observed a cyclone and photographed it. This is in the vicinity of Australia.

Television Interview with G. T. Dobrovol'skiy

22 June 1971

Zarya-25. Today we are asking you to tell about the biological experiments connected with the effect of weightlessness on the growth and development of high-altitude plants. Could you start our interview?

Yantar'-1. Zarya, I am Yantar'-1. I am passing you to Yantar'-2. We have many compartments with scientific equipment. He is now entering one of them and will show you the research subjects themselves.

Zarya-25. We see you excellently.

Yantar'-2. Comrades, today we can continue familiarization with our orbital station, with the large and broad program of scientific experiments. We shall tell you about what is in our power, what time permits, about the large complex of biological studies being conducted onboard. I now show you the compartment, a special compartment in which our pets are located — 9 plants. However, to do this I must float.

Zarya-25. The parting will be short, we shall observe you.

Yantar'-1. I want to show you a special compartment where we have the container with the plants. This container has been called the Oasis.

Zarya-25. Now we see the container excellently on the screens.

Yantar'-1. In this container there are 9 pots in which the seeds of various plants were put into the orbit of the artificial Earth satellite.

Zarya-25. Which ones?

23 JUNE

Flight Control Center, 23 June 1971. By 1200 hours Moscow time the Salyut manned scientific station completed the 261-st orbit around the Earth.

The new working day onboard the station began earlier than the rest for Flight Engineer Vladislav Volkov. After 6 hours, the crew Commander Georgiy Dobrovol'skiy set to work, and then the Test Engineer Viktor Patsayev.

The program for the day was executed. Georgiy Dobrovol'skiy studied the optical characteristics of the visual orientation instrument -- a wide-angle viewer. In particular, he investigated the dispersion characteristics of the various projection screens of this instrument considering the actual brightnesses and contrasts of the Earth's surface. In addition, Dobrovol'skiy performed experiments with respect to the triaxial orientation of the station. Vladislav Volkov used one of the navigational instruments to monitor the experiments. During the execution of the operations with respect to orientation and control of the station movements, Viktor Patsayev made studies of the light effects occurring during operation of the control engines. In addition, Viktor Patsayev studied the effect of the cosmic medium on the optical surfaces of the ports having different chemical coatings.

The observations and photographing of the Earth's surface in the interests of the national economy continued: the objects of study were the regions of Central Kazakhstan and Pamir.

Yesterday at 1748 hours Vladislav Volkov observed the cyclone in the vicinity of the Indian Ocean with the coordinates of 45 degrees south latitude and 60 degrees east longitude. These data were confirmed by the results obtained from the meteorological satellite.

During the course of the work, the cosmonauts continued to study the various functions of the organism under the conditions of prolonged space flight. According to the medical control data no visible deviations from the normal state of the organism were observed in Dobrovol'skiy, Volkov and Patsayev.

According to the reports of the cosmonauts and the data from telemetric information, the onboard systems and apparatus of the station and also the parameters of the microclimate are normal. At 0940 hours the Salyut station left the zone of radio contact with the territory of the Soviet Union.

24 JUNE

Flight Control Center, 24 June 1971. The crew of the Salyut orbital scientific station is in space after 18 days. Thus, this flight is the longest of all manned space flights ever attempted before.

All members of the crew feel good. According to the medical monitoring data, the pulse rate at rest for Georgiy Dobrovol'skiy is 72, for Vladislav Volkov it is 68, and for Viktor Patsayev it is 74 beats a minute. The respiration rate for Dobrovol'skiy is 20, for Volkov it is 12 and for Patsayev it is 18. The arterial pressure is 110 over 78, 110 over 70 and 130 over 75 millimeters of mercury respectively.

One of the experiments performed by the program for the next working day was photographing the stars and the Earth in various modes of manual and automated orientation of the station. The photographing also was done during turns of the station with respect to various axes and with different angular velocities. The photographs were taken by special automated cameras after strictly defined time intervals.

The experiment performed permits investigation of the behavior of the station for various modes of controlling its movement and also determination of the nature of the deformation of its hull under the effect of various factors on a prolonged space flight.

In addition, the results of synchronous photography of the stars and the Earth permit an increase in accuracy of the subsequent processing of the pictures of the Earth's surface taken in the interests of geology, geodesy and cartography and also an increase in accuracy of the coordinate gridding of the results of the astronomical

As has already been reported, this system permits investigation of the phenomenon of electron resonance in the high-frequency fields, measurement of the parameters of the ionosphere, the spatial distribution of the charged particles near the station, the potential of its hull and also other processes and physical phenomena accompanying the movement of the station in a rarefied plasma.

The studies performed earlier demonstrated the normal functioning of the electronsmodules and the automation circuitry. A procedure for ionospheric measurements was more precisely defined, and the optimal operating conditions of the instruments were selected.

On 25 June the Test Engineer Viktor Patsayev took measurements of the parameters of the ionosphere on different sections of the orbit; then studies were made of the electron resonance on special antennas of different geometric configuration. The required values of the electrical parameters were introduced into the apparatus, and the programs for the performance of studies of physical relations were given. The orders to take the measurements which were automatically processed by the equipment were issued. The values of the investigated parameters and the operating regime of the system for recording them were monitored by Viktor Patsayev by the readings of the pointer indicators and also using a cathode ray oscilloscope; then the spatial distribution of the high-frequency electromagnetic field near the antennas was measured.

According to the data from the telemetric information and the reports of the crew Commander Dobrovol'skiy, the cosmonauts feel well. In the station compartments normal conditions are being maintained. By 1300 hours Moscow time, the Salyut manned scientific station completed the 291-st turn around the Earth.

From the Verbatim Radio Conversation of the Crew with the Flight Control Center

25 June 1971. 0257 hours

Zarya. Do you feel all right?

Yantar'-1. Yes, I feel normal. I feel good. Transmit to the command that everything is going according to plan. Even some of the experiments which you did not plan we are trying to do in addition to the ones you are giving us. Well, how do you feel about that.

Zarya. All right, but not at the expense of rest.

25 June 1971. 0312 hours

Yantar'-1. We have begun to notice that our eyes get tired during the work day. The bright light and then the transition to the shadow. And in the spacecraft there is darkness. It appears that there is little illumination. But everything is normal.

We observed a cyclone at 0322 hours, 12 degrees north latitude, 128 degrees east longitude. Very severe.

Zarya. I read you. One minute until the end of the session.

Yantar'-1. We understand. Over and out.

25 June 1971. 0431 hours

Yantar'-1. Transmit to the meteorologists that with respect to cyclones we have never observed all of them. As a rule, their recommendations are very useful and suit the purpose exactly.

25 June 1971. 0720 hours

Yantar'-2. Now I have done my physical exercises. The recommended exercises. I had a great weight. I became tired, I even enjoyed it.

Zarya. That is good. Our medical specialists are very happy that you have worked so well.

Yantar'-2. I tried to do everything as stipulated and loaded myself.

Zarya. Well, now you see that everything is good...

Yantar'-2. I don't know whether that is good or bad.

Zarya. Good, good. The medical specialists say it is good.

Television Interview with G. T. Dobrovol'skiy

25 June 1971

Yantar'-1. A great deal of work was done which is exceptionally important with respect to its scientific content. We have completed a more than three-week flight. Now the crew is making preparations for the descent. The equipment, documents, part of the scientific apparatus are being packed in the transport ship. Many interesting materials and data will reach the Earth which the scientists, engineers, technicians and workers are awaiting impatiently. In addition, we in human fashion are missing the Earth and impatiently, of course, await our return.

Zarya-25. We see you excellently. Tell us please, what are you doing now?

Yantar'-1. Now? Well Yantar'-2, he is going to bed early. His time to sleep comes early. Then I go to bed, and then Viktor Ivanovich Patsayev. Then we shall get up, make ourselves secure before the descent and take our seats...

Zarya-25. You know, dear friends, we have watched your unprecedented flight with enormous attention, we have been inspired by your courage and really excellent work. We wish you a very happy return to your native Earth. We shall see how you descend from orbit. At this time we wish you successful completion of the flight and a soft landing.

Yantar'-1. Thank you very much. To a quick return to Earth.

Zarya-25. Really, to a quick return to Earth.

Yantar'-1. Don't worry, everything will be alright with us.

Zarya-25. We are absolutely certain of that. A happy flight and successful landing.

Yantar'-1. Thank you very much.

Zarya-25. I am bringing the last space viewing session to a close; again a happy flight and a soft landing.

26 JUNE

Flight Control Center, 26 June 1971. Today at 0804 hours Moscow time the time spent by Cosmonauts Dobrovol'skiy, Volkov and Patsayev in space flight in Earth orbit reached 20 days.

The program for the next working day of the crew of the Salyut station included scientific-technical experiments. The cosmonauts recorded the intensity of charged particles and the charged spectrum of the cosmic radiation nuclei in order to check the hypothesis of group acceleration of particles in outer space.

The station crew continued the experiments with respect to measuring the magnitudes of the fabric radiation doses. Simultaneously, the equipment on the outside of the station hull was used to record the high energy particle flux. In addition, experiments were run to study the micrometeoritic situation in outer space.

During the course of working according to the program of the day, the cosmonauts did various physical exercises more than once and performed medical checks. The state of health of all members of the crew is good.

The onboard systems of the Salyut station are functioning normally. According to the data from the telemetric information, the temperature in the operating compartment is 22°C, the pressure is 880 mm Hg, and the gas composition is normal.

The flight of the Salyut manned scientific station is continuing.

From the Daily Log of V. N. Volkov

26 June 1971. The 21-st day of flight has come. Zarya has congratulated us on setting the new world record for time in outer space. How pleasant these congratulations are, especially here in space. It touches us to tears. The boys have slept while I maintained communications and received these congratulations. I did not want to wake them. However, they, feeling this, without a word, crawled out of their sacks. Our sleeping areas resemble a beehive

(in the forest) where bees are flying in and out. There are also small openings into which we crawl when sleep time comes and emerge when we hear the command to wake up (this means the duty officer awakens you by touching your shoulder and sometimes your head).

By the way, about sleeping. For some reason I have slept very little these two days. In all I have slept a total of three hours. I can not force myself. Yesterday I even decided to read Yevgeniy Onegin before going to sleep and was surprised that I passed an entire hour. However, the book did not help. I did not have dreams on my last flight. Now I have as many dreams as you want, even more than on Earth.

From the Verbatim Radio Conversations Between the Crew and the Flight Control Center

26 June 1971. 1014 hours

Zarya. Yantar, Zarya is listening. What are you sighing about?

Yantar'-1. I am sighing about the fact that I am looking into the medical sensors. Oh my God!=

Zarya. How many terminals?

Yantar'-1. My, my, my. Those brilliant medical specialists! Right arm, left leg...

26 June 1971. 1736 hours

Zarya reports to Yantar'-2 the telemetric data on the onboard climate.

Zarya. The climate, we shall say, is good where you are. Here they are complaining about how it is with us.

26 June 1971. 1841 hours

Yantar'-1. What research are they talking about?

Zar Zarya. Medical. What you did not do today you must do everything exactly tomorrow. In addition, we shall give you the time to do it all.

Yantar'-1. The fact is the following. When the dynamic operations are underway, then we shall prepare for them. Now we are setting up so that next time we are asked, we are ready for the analyses. You will take all of this into account. We are trying to work just as on the ground except the work conditions are quite different. We are trying to do the same amount of work as on the ground. That is why we do not have enough time.

From the Daily Log of V. N. Volkov

26 June 1971. 1700 hours. The end of the day is approaching, tomorrow is Sunday. Before going to sleep we changed the tanks of the cooling-drying unit of the sanitation unit and the drinking water tank.

... I tried the counter-g-load suit: this is for landing.

From the Daily Log of G. T. Dobrovol'skiy

26 June 1971. Volod'ya Shatalov read an excerpt from Pravda. The City Council of Odessa has elected me an honorary citizen of Odessa.

The regime for intensified physical training has been transmitted from the ground.

Soon the descent!

27 JUNE

Flight Control Center, 27 June 1971. On 27 June, the 22-nd day of space flight began for Georgiy Dobrovol'skiy, Vladislav Volkov and Viktor Patsayev. At 1200 hours Moscow time, the orbital scientific station Salyut completed the 1120-th orbit around the Earth, including 326 orbits with the crew onboard.

In accordance with the flight program the next day was devoted to the check-out of the onboard systems of the station and the Soyuz-11 transport ship. The cosmonauts performed a set of physical exercises. They did medical monitoring and rested in turns.

In the television interview transmitted from onboard the station, the crew members told about the execution of the program of scientific-engineering and medical-biological experiments and also the food and methods of storing and heating it.

According to the reports of the cosmonauts and the telemetric data, Dobrovol'skiy, Volkov and Patsayev feel good. All of the onboard systems of the orbital station are functioning normally. The manned space flight is continuing.

From the Verbatim Report of the Radio Conversations of the Crew with the Flight Control Center

27 June 1971. 0232 hours

Yantar'-1. Everyone's blood pressure is normal: Yantar'-3 -- 115/75; Yantar'-1 -- 120/70; Yantar'-2 -- 115/60. After the load, the pressure and pulse are very quickly recovered: it was 140/55 and immediately, literally after 1 minute, it returned to normal, not like on Earth.

27 June 1971. 0827 hours

Yantar'-1. We have a question with respect to the sleep schedule. We have found that at 1240 hours the third person must go to sleep, but at 1400 hours the second person gets up. At that time the first person is also resting.

Zarya. That is correct. We are beginning slowly to equalize you. Do you understand?

Yantar'-1. The equalization plan is understood. But the station remains without a watch?

Zarya. The decision of the control group stands. Have you understood me correctly.

Yantar'-1. I understand. However we do not want to do this.

Zarya. Do it, do it, as indicated in the program. Everything is going well. Everything is in order onboard. Don't sigh, it must be done. The control group says that this procedure is necessary.

Yantar'-1. I understand.

Zarya. It is necessary to carry out the schedule. We are tracking clearly by telemetry and if necessary, we shall arouse you, do not worry.

Zarya. Don't forget that now your assignment is to rest.

Yantar'-2. We are planning a rest day so that we can nap a little because during the working days there is very little time for this. We shall pick up our physical culture a little, we have done few exercises for an entire week but today we shall try to do them. Of course, we shall not do this so sharply. We shall adjust little by little (to the load).

27 June 1971. 1342 hours

Yantar'-2. Take down the cyclone observations:

The southern part of America. Coordinates: 22 degrees east longitude and 46 degrees south latitude. Powerful growing cyclone. Observation time 1339 hours.

Zarya. Roger, over and out.

Remote Interview with V. I. Patsayev

27 June 1971

Zarya-25. Very many television viewers and radio listeners want to know how you are eating.

Yantar'-3. Our food is either in cans or in tubes. The dessert is in packages: prunes, candied fruit. All of this is stored in two refrigerators. The refrigerators are very large capacity. The tubes and juices are stored in special containers. The food in tubes is heated on two heating elements.

Zarya-25. You have been in spece for 22 days. Has your weight changed?

Yantar'-3. We think not.

Zarya-25. What do you do in your spare time?

Yantar'-3. We have very little of it. In our spare time we read. We have a library (Lermontov, Pushkin, Tolstoy). We listen to music. We have a tape recorder with films.

28 JUNE

Flight Control Center, 28 June 1971. On the morning of 28 June, the 23-rd day of orbital flight of Cosmonauts Dobrovol'skiy, Volkov and Patsayev began. By 1200 hours Moscow time, the Salyut manned scientific station had completed 342 orbits around the Earth.

During the flight the studies of the cardiovascular system of the cosmonauts was continued using the apparatus designed for periodic medical examinations. In particular, measurements were taken of the arterial pressure, the duration of the cardiac phases at rest and after functional loads. According to the medical monitoring data, the pulse rate at rest for Georgiy Dobrovol'skiy is 72, for Vladislav Volkov it is 64 and for Viktor Patsayev it is 72. The respiration rate is 16, 18 and 16 per minute respectively, and the arterial pressure is 115 over 70, 115 over 68 and 115 over 75 mm Hg respectively.

During the day the cosmonauts checked the onboard systems and units of the station. According to the reports of the crew and the telemetric data, all of the onboard systems of the station are functioning normally. The crew members Dobrovol'skiy, Volkov and Patsayev feel good. The flight of the orbital scientific laboratory is continuing.

29 JUNE

Flight Control Center, 29 June 1971. By 1200 hours Moscow time, the Salyut manned scientific station will have completed 358 orbits around the Earth. The Cosmonauts Dobrovol'skiy, Volkov and Patsayev have been in space flight 24 days.

The next working day of the Salyut station crew took place in accordance with the established schedule. The cosmonauts performed mutual medical checks, they made entries in the logs about the experiments performed. During the day the crew checked the scientific equipment and the onboard systems of the station. During the radiocommunication sessions the cosmonauts reported on the research performed onboard the station and how they felt.

According to the report of the crew Commander Dobrovol'sky, all of the cosmonauts feel good. In the station compartments conditions are being maintained which are similar to the Earth. All of the onboard systems of the station are functioning normally. The flight of the manned scientific station Salyut is continuing.

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

29 June 1971. 1649 hours

Zarya. Good morning.

Yantar'-2. Good morning.

Zarya. How do you feel?

Yantar'-2. I feel good.

Zarya. And how is your mood?

Yantar'-2. As always. We are going according to the schedule. We shall now put on our suits. Everything is in order. The onboard systems of Soyuz are operating normally.

Yantar'-2. How is the weather in the area?

Zarya. Excellent weather, everything is ready, we are waiting for you.

29 June 1971. 2115 hours

Zarya. Give the command to close the transfer hatch.

Yantar'-2. I am givkng the command.

Zarya. On closing the transfer hatch open the hatch of the descent spacecraft, check it again and then check that it is closed.

Yantar'-3. The hatch open light has gone out.

Zarya. Everything has been understood. I give you permission to disengage.

Yantar'-3. The disengage command was sent at 212515 hours.

Yantar'-2. Separation has taken place, separation has taken place... We see separation visually. The station has passed to our left with rotation.

Zarya. Landing will take place 10 minutes before sunrise.

30 JUNE

From the Verbatim Radio Conversations of the Crew with the Flight Control Center

30 June 1971. 0016 hours

Yantar'-2. Everything is normal... Everything is good. We feel good ... We are trying to crawl into the chairs. We have crawled.

Yantar'-1. We are proceeding according to program. The Earth is appearing a little. We are beginning orientation. The station is flying off to the right. It is beautiful. Now we are beginning orientation.

Yantar'-3. I see the horizon in the lower section of the port.

Yantar'-2. The light is burning: the descent light. The SOUD[1] inhibit mark is burning. Normal.

Zarya. All right.

Yantar'-1. We have checked the systems. Everything is normal. The horizon has come up for me. The station is above me.

Zarya. Goodbye, Yantari, to the next contact.

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[1] Motion orientation and control system.

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